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The effect of physical activity on the subjective well-being of rural left-behind children: the mediating role of discrimination perceptions and loneliness

Fazhao Feng^{1†}, Huanyu Li^{1*} and Ting Zhang^{2†}

Abstract

Objective This study explored the mediating role of perceptions of discrimination and loneliness on the relationship between physical exercise and subjective well-being in rural left-behind children.

Methods A package of surveys were administered to junior high school students and senior primary school students ($n = 592$) in the countryside, which including the scale of the *Physical Activity Behavior Scale*, *Subjective Well-Being Scale*, *Perceived Discrimination Scale*, and *Loneliness Scale*. *Structural Equation Modeling* and *Bootstrap* were used to analyze the data to investigate the chain mediating effect of perceived discrimination and loneliness.

Results (1) There was a positive correlation between physical activity and subjective well-being, and the direct prediction of subjective well-being was significant. (2) Physical activity negatively predicted perceptions of discrimination, and perceptions of discrimination positively predicted loneliness and negatively predicted subjective well-being, and loneliness could negatively predict subjective well-being. (3) Perception of discrimination and loneliness significantly mediated the relationship between physical activity and subjective well-being. The mediating effect consisted of indirect effects generated by 2 paths, one was that physical exercise indirectly affected subjective well-being by affecting discrimination perception, and the other was that physical exercise further acted on subjective well-being through the chain mediating effect from discrimination perception to loneliness.

Conclusion Physical exercise can directly affect the subjective well-being of rural left-behind children. Physical exercise can indirectly affect left-behind children's subjective well-being through discrimination perceptions, and it can also indirectly affect left-behind children's subjective well-being through the chain mediating effect of discrimination perceptions and loneliness.

Keywords Rural left-behind children, Physical activity, Subjective well-being, Discrimination perception, Loneliness

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Introduction

The problem of left-behind children has been in the public eye in recent years. In recent years, with the advancement of reform and opening up in China, urbanization has been accelerating in many places, with a large number of rural laborers flowing into the cities, but due to a series of practical problems, such as labor treatment, family economic situation, and family choices, a large number of children of migrant workers are forced to stay in the countryside [1]. Some studies have shown that left-behind children are significantly lower than non-left-behind children in terms of satisfaction with family, schooling, freedom, environment, and overall life satisfaction [2]. In terms of emotional experience, some studies have shown that left-behind children experience more negative emotions compared to the average student [3]. Therefore, it is of theoretical and practical significance to explore the influencing factors and mechanisms of left-behind children's subjective well-being and then to adopt effective strategies to improve their subjective well-being, to help left-behind children cope with stressful events in their lives and maintain their psychological health.

Among the many factors affecting subjective well-being, physical exercise, as a common activity of leisure and recreation in modern society, can produce many positive psychological benefits, and its impact on subjective well-being has attracted much attention from scholars [4]. However, there are few studies at home and abroad on whether the subjective well-being of left-behind children can be regulated by physical exercise. Based on the psychological problems of left-behind children, this paper focuses on explaining how physical exercise regulates the negative emotions of left-behind children and improves their subjective well-being at the same time, to provide ideas for improving the well-being of left-behind children.

The definition of left-behind children has been explained by many scholars and relevant State departments. In 2014, the Ministry of Education of China issued the 2014 National Education Development Statistics Bulletin, which pointed out that rural left-behind children refer to children of school age who are under the custody of their fathers, mothers, or other relatives, who are left behind in their hometowns, where their parents have gone out to work for more than three consecutive months, and who are under the supervision of their fathers, mothers or other relatives, and who are subjected to compulsory education [5]. China's State Council pointed out in the Opinions on Strengthening the Care and Protection of Rural Left-behind Children that left-behind children refer to minors under the age of sixteen who are not capable of being supervised by both of their parents going out to work or by one of the parents going out to work [6]. Therefore, the definition of left-behind

children in rural areas in this paper is: in the compulsory education stage of adolescents in rural areas, because one or both parents go out to work and are left behind in the rural household registration area, the time left behind is more than three consecutive months, and children under the age of sixteen years old are raised and educated by a single parent or relatives.

Subjective well-being is a holistic assessment of the assessor's quality of life based on self-defined criteria, which is a comprehensive psychological indicator of the quality of life of an individual, reflecting the subject's social functioning and adaptive state [7], and at the same time, subjective well-being is also a cognitively and emotionally subjective evaluation of an individual's own life [8]. As the recipients of rural education, the subjective well-being of rural left-behind children is an important factor in promoting rural construction as well as stabilizing urban and rural development. Since subjective well-being is not only genetically controlled but also depends largely on an individual's choice of meaningful activities, choosing meaningful activities regularly is important for "pursuing" and "maintaining" long-term subjective well-being [9]. Currently, there is less literature that directly describes the extent and percentage of Chinese adolescents' overall subjective well-being. Most studies have concluded that Chinese adolescents' subjective well-being is high overall, but there are significant regional and individual differences. For example, adolescents in the eastern region generally have higher levels of subjective well-being than those in the central and western regions, and adolescents in urban areas have higher levels of subjective well-being than those in rural areas. In addition, there are differences in subjective well-being among adolescent students of different genders, grades, and family economic statuses [10].

Physical exercise is a conscious activity in which people take the initiative to transform and improve the subject themselves, and the activities of physical exercise include fitness and bodybuilding exercise, entertainment and leisure exercise, health care and rehabilitation exercise, and psychological intelligence exercise [11]. Physical exercise can reduce the ability of negative emotions such as depression and loneliness while obtaining psychological pleasure, which in turn has an impact on subjective well-being [12]. Studies have shown that physical activity induces changes in brain structure and function, with effects on cognitive function and subjective well-being [13]. Existing studies have shown that appropriate physical activity affects subjective well-being [14], while physical activity can also affect subjective well-being through different mediating variables [15]. Physical activity was found to be positively associated with positive affect and life satisfaction [16]. Currently, studies have shown that there are obvious regional and grade-level differences

in Chinese adolescents' choice of after-school activities, daily exercise plans, homework time consumption, in-school and out-of-school time disposal, and arrangements for weekend and holiday activities, etc.; economic factors, policy factors, awareness and methods, habit formation, external conditions, and classroom pressures are constraints hindering adolescents' participation in extracurricular physical activity; the most important factors affecting adolescents' participation in physical activity are exercise interest, exercise motivation, different grade levels, sports awards, school sports characteristics, fitness awareness, applicability of fitness methods, and rigor of fitness tests. The most important factors affecting adolescents' participation in physical activity are interest in exercise, motivation for exercise, different grades, sports awards, school sports characteristics, awareness of fitness, applicability of fitness methods, and rigor of physical fitness tests [17].

Accordingly, Hypothesis 1: There is a positive effect of physical activity on subjective well-being.

Some studies have shown that physical activity can increase positive emotional experiences and decrease negative emotional experiences [18], and physical activity input of secondary school students is significantly positively correlated with life satisfaction and positive emotion in subjective well-being, and significantly negatively correlated with negative emotion [19]. Discrimination perception refers to the individual or the group to which the individual or the group belongs to be treated differently or unfairly, which can be divided into individual discrimination perception and group discrimination perception [20]. Due to the lack of parental care, left-behind children are ridiculed as "unwanted children", which leads to the perception of individual discrimination [21]; while the media's increased exposure of some cases strengthens the public's negative impression of them, and they are regarded as "problem children", which leads to the perception of group discrimination. The media's increased exposure of some cases reinforces the public's negative impression of them as "problem children", leading to the perception of group discrimination [22]. It has been suggested that physical activity is an adaptive coping strategy to prevent negative mental and physical health problems caused by stressful events such as discrimination [23] and that discrimination has a detrimental effect on subjective well-being [24].

Accordingly, Hypothesis 2 is proposed: discrimination perceptions play a mediating role in the positive effect of physical activity on subjective well-being.

Loneliness is the subjective experience of an individual who feels dissatisfied with social relationships and life [25]. Harris et al. found that loneliness during childhood is closely associated with sleep disorders, depression, and health problems during adolescence [26], and is

accompanied by poor academic performance, high dropout rates, and high crime rates [27]. Some studies have shown that physical activity has a significant negative effect on loneliness, such as when the amount of physical activity of college students is higher, their loneliness level is lower [28], in addition, some studies have suggested that loneliness correlates with life satisfaction, such as with the increase of loneliness, life satisfaction decreases [29]; at the same time, with the decrease of positive emotional experience and the increase of negative emotions, loneliness also increases [30].

Accordingly, Hypothesis 3 is proposed: loneliness plays a mediating role in the positive effect of physical activity on subjective well-being.

There was a significant positive predictive relationship between discrimination perception and loneliness for both two-parent out-of-home adolescents and father out-of-home pro-adolescents, suggesting that the level of discrimination perception is a significant risk factor for loneliness among left-behind adolescents [31]. One study confirmed that discrimination perceptions among long-term migrant children were significantly and positively associated with loneliness, social anxiety, and depression, with discrimination having the greatest impact on loneliness [32]. Perception of discrimination is thus an important predictor of children's loneliness, and discrimination perceptions are likely to have a detrimental effect on children's loneliness. Therefore, hypotheses 1–3 are synthesized, and it is believed that there may be a chain mediation path of "physical exercise → discrimination perception → loneliness → subjective well-being", and that the internal mechanism of physical exercise empowering left-behind children's subjective well-being may be as follows: Participation in physical exercise promotes left-behind children's elimination of discrimination, better integration into the group, and then elimination of loneliness and improvement of left-behind children's subjective well-being. The intrinsic mechanism of improving left-behind children's subjective well-being may be as follows: participation in physical exercise can help them eliminate discrimination, better integrate into the group, and thus eliminate their sense of loneliness.

Accordingly, Hypothesis 4 was proposed; discrimination perceptions and loneliness play a mediating role in the positive effect of physical activity on subjective well-being.

The overall purpose of this paper is to explore whether physical exercise can effectively enhance the subjective well-being of rural left-behind children and to analyze in depth the chain-mediated roles of discrimination perceptions and loneliness in this context. Theoretically, it is to find out whether left-behind children have negative psychological experiences due to discrimination and loneliness, and whether physical activity can indirectly

enhance their subjective well-being by alleviating and decreasing perceptions of discrimination and loneliness. In addition, the study examines whether physical activity first affects perceptions of discrimination, then affects loneliness through perceptions of discrimination, and ultimately affects subjective well-being. From a practical point of view, targeted policy and practice recommendations are proposed to promote the active participation of rural left-behind children in physical exercise, reduce the perception of discrimination and loneliness, improve the mental health of left-behind children, and promote the development of their positive psychological qualities.

Research methods

Sample and data collection procedure

This study used a stratified whole cluster random sampling method to survey 592 upper primary and middle school students from 2 rural general elementary schools and 1 rural general secondary school in 3 townships of Xiaogan City, Hubei Province, from December 1 to December 15, 2022, by distributing paper questionnaires. It should be noted that while the city's resident population at the end of 2023 in Xiaogan City was 4,172,000 people, the city's total household population at the end of 2023 was 4,973,000 people. This means that a large portion of the city's population is working outside of the city, which is bound to result in the creation of left-behind children. At the same time, the city has 429 general elementary schools and 227 general secondary schools (including schools in the city). The student enrollment in the three schools sampled in this paper is geared towards rural children, most of whom have parents who work outside the city all year round.

A total of 592 scales were distributed and 592 were returned. Four criteria were used to eliminate invalid scales: (1) more than 20% of the questions on the paper-based scales were omitted; (2) the proportion of the same number appearing in the fill-in answers of a single scale was more than 70%; (3) Z-values were calculated between each dimension, and those with standardized values of more than ± 3 were excluded; (4) missing values were filled in using the serial mean based on the first three items, and a Pearson correlation analysis, and found that there was no significant correlation between the amount of exercise and discrimination, eliminating the regularity

of answers between scales of different dimensions. In this article, left-behind children were defined as children under 16 years of age who were separated from both or one parent for more than three consecutive months when both parents went out to work, or one parent went out to work, and they were taken care of by their grandparents, relatives or friends [33]. Five hundred and ninety-two scales were recovered, and finally, 476 were scales that met the conditions of the subjects, with a total of 73 invalid scales being excluded, resulting in 403 valid scales, with an effective recovery rate of 84.66%.

Among them (Table 1), 205 (50.9%) were boys and 198 (49.1%) were girls; 75 (18.6%) were fifth-grade students, 76 (18.9%) were sixth-grade students, 95 (23.6%) were Middle 1 students, 80 (19.9%) were Middle 2 students, and 77 (19.1%) were Middle 3 students. The average age of the sample was 13.17 ± 1.46 , the average age of the fifth grade was 11.41 ± 0.52 , the average age of the sixth grade was 12.03 ± 0.33 , the average age of the first grade was 13.04 ± 0.62 , the average age of the second grade was 14.10 ± 0.59 , and the average grade level of the third grade was 15.21 ± 0.71 . It is important to note that China's school system is one in which a child starts at age six and entering elementary school begins with a six-year school system for elementary school, a three-year school system for junior high school, and a three-year school system for senior high school.

Measurement tools

Measurement of physical activity behavior

Subjects' physical activity intensity, time, and frequency were investigated using the Physical Activity Rating Scale revised by [34]. Physical activity = intensity \times (time-1) \times frequency, intensity, time, and frequency were divided into '5' grades, which were scored from 1 to 5, with a maximum score of 100 and a minimum score of 0, respectively.

Subjective well-being measurement

To evaluate subjective well-being more comprehensively, life satisfaction and positive scales were used as evaluation indicators of subjective well-being. The subjective well-being questionnaire developed by Diener et al. [35] and Bradburn's Positive and Negative Affective Scale [36] were used, and the Chinese translations translated by

Table 1 Participate profile

	Total (N=403)	fifth-grade (N=75)	sixth-grade (N=76)	Middle 1 (N=95)	Middle 2 (N=80)	Middle 3 (N=77)
N (%)	100%	18.6%	18.9%	23.6%	19.9%	19.1%
Age, M (SD)	13.17 (1.46)	11.41(0.52)	12.03 (0.33)	13.04(0.62)	14.10(0.59)	15.21 (0.71)
Gender						
Boy	205 (50.9%)	42 (56%)	31 (40.8%)	51 (53.7%)	38 (47.5%)	43 (55.8%)
Girl	198 (49.1%)	33 (44%)	45 (59.2%)	44 (46.3%)	42 (52.5%)	34 (44.2%)

Ms. Feng Xia from Central China Normal University in her master's thesis and by Chen Wenfeng were partially selected for this study. The questionnaire included overall life satisfaction ('5' questions) and a positive affective scale ('7' questions). Life satisfaction was scored on a 7-point scale from "strongly oppose" to "strongly favor"; the positive scale was scored on a 4-point scale from "do not have" to "often have". The positive scale was rated on a 4-point scale from "not at all" to "often". In this study, the two scales were combined to form a first-order two-factor model for specific research analysis. The study concluded that the Cronbach's alpha coefficient of the subjective well-being scale was 0.886, the measurement model fit $X^2/df=2.718$, $CFI=0.963$, $TLI=0.954$, $RMSEA=0.065$, and $SRMR=0.037$, and the structural validity of the scales was good. The factor loadings for the five questions of the Life Satisfaction Scale were 0.766, 0.782, 0.843, 0.740, 0.407; and for the Positive Affect Scale, 0.765, 0.749, 0.808, 0.704, 0.703, 0.727, 0.720. The factor loadings for life satisfaction and positive emotions were 0.770 and 0.969. Comrey (2013) argued that it is recommended to use a series of more detailed cutoffs to assess factor loading quality, specifically 0.32 (poor), 0.45 (fair), 0.55 (good), 0.63 (very good), and 0.71 (excellent) [37]. The fifth question on Life Satisfaction was in the middle of poor and fair and was not removed because it did not affect the structural validity of the CFA.

Measurement of perceived discrimination scale for left-behind children

The Perceived Discrimination Scale developed by Shen Jiliang et al. (2009) was used [21], which contained 'six' questions, three of which examined individual perceived discrimination and the other three examined group perceived discrimination, and was scored on a 5-point scale, with higher scores representing higher levels of perceived discrimination. Since the first three questions and the last three questions examined different perspectives, the same two dimensions constitute a first-order two-factor model way to conduct specific research. The Cronbach's alpha coefficient of the Perceived Discrimination Scale for Left-behind Children was found to be as follows with a Cronbach's alpha coefficient of 0.831, measurement model fit $X^2/df=3.652$, $CFI=0.977$, $TLI=0.957$,

$RMSEA=0.081$, $SRMR=0.027$. The factor loadings for the six questions of the scale were 0.733, 0.810, 0.668, 0.825, 0.762, and 0.737. The factor loadings for individual perceived discrimination and group perceived discrimination were 0.826 and 0.819. And good structural validity of the scale.

Measurement of students' loneliness scale

Students' loneliness dimensions selected from the Zhang Kuo Loneliness Scale (CLS) [38] were used, which consisted of 6 questions with a 5-point scale, ranging from "completely meets" to "does not meet at all", with reverse scoring. In this study, the Cronbach's alpha coefficient of the Student Loneliness Scale was 0.916, the measurement model fit was $X^2/df=10.24$, $CFI=0.951$, $TLI=0.919$, $RMSEA=0.154$, and $SRMR=0.034$, which indicates that the structural validity of the scale is good. The factor loadings for the six questions of the scale were 0.714, 0.848, 0.838, 0.869, 0.892, 0.649. The structural validity of the scale was fair, and it was speculated that the fit was poor due to the loneliness dimension being affected by extreme values.

Statistical methods

IBM SPSS Statistics 27 software was used for descriptive statistics, correlation analysis, reliability and validity tests of the scale, and Mplus 8.3 software was used for structural equation modeling to test model fit and mediation effects. The bootstrap method was used to estimate the chained mediation effect to ensure the statistical effect.

Result

Kline suggests that an absolute value of less than 3 for skewness and less than 10 for kurtosis are acceptable criteria. [39] Therefore, the main variables in this paper conform to normal distribution (see Table 2).

Common variance bias test

The data used in the study were all from paper questionnaire tests, and there is a possibility of a common method bias problem. Harman's one-factor modeling method was used to test the common method bias problem, and the results showed that the exploratory factor analysis extracted a total of six factors with eigenvalues greater

Table 2 Descriptive statistical analysis of the variables

Variables	N	M ± SD	MIN	MAX	Sk	Kur
Physical activity	403	22.01 ± 19.10	1.00	100.00	1.470	2.543
Life satisfaction	403	4.11 ± 1.38	1.00	7.00	-0.008	-0.318
Positive affective	403	3.09 ± 0.73	1.00	4.00	-0.461	-0.499
Individual discrimination	403	1.96 ± 0.86	1.00	5.00	1.068	1.523
Group discrimination	403	1.72 ± 0.73	1.00	5.00	0.730	1.252
Loneliness	403	2.16 ± 1.01	1.00	5.00	0.744	-0.212

than 1, and the explained variance of the first factor was 36.40, which was lower than the critical value of 40, indicating that there was no common method bias problem.

Correlation matrix of each variable

As can be seen from Table 3, there is a significant positive correlation between Physical Activity (PA) and Life Satisfaction (LS) and Positive Emotion (PE), and a significant negative correlation between physical activity and Discrimination Perceptions (DP) and Loneliness (L), and the correlation coefficients of each variable are significant, which provides support for further construction of structural equation modeling.

Hypothesized Model Testing

To effectively control the measurement error, the structural equation modeling method was used to conduct the chain mediation effect test to detect the fit of the overall model when subjective well-being was used as the dependent variable. The model was set up and tested in Mplus software, and the results showed that the total effect of physical activity affecting subjective well-being was significant, with a total effect of 0.257 ($P < 0.05$), and the direct effect of physical activity affecting subjective well-being was 0.145 ($P < 0.05$). The strengths and weaknesses of the model were judged using the model fit indicators provided by the Mplus software, chi-square/degrees of freedom (the smaller, the better) comparative fit indicators CFI (> 0.9), Tucker-Lewis index TLI (> 0.9), root mean square of approximation RMSEA (< 0.05 or 0.08), standardized root mean square residual SRMR (< 0.08). The model was judged to be well fitted by the above criteria: $\chi^2/df = 2.357$, CFI = 0.936, TLI = 0.927, RMSEA = 0.058, SRMR = 0.047 (see Fig. 1).

The Bootstrap method was used to test the significance of each variable between physical activity and subjective well-being as a way of determining which paths may have indirect effects (See Table 4). The Bootstrap was set to sample 3,000 times to estimate the total and indirect effects. As shown in Table 4, the β -value between physical activity and subjective well-being was 0.134 (95% CI = [0.060, 0.213]); the β -value between physical activity and discrimination was -0.155 (95% CI = [-0.264, -0.033]); and the β -value between discrimination and subjective well-being was -0.213 (95% CI = [-0.368, -0.051]); the beta

between physical activity and loneliness was -0.051 (95% CI = [-0.147, 0.052]); the beta between loneliness and subjective well-being was -0.557 (95% CI = [-0.698, -0.401]); and the beta between discrimination and loneliness was 0.600 (95% CI = [0.478, 0.717]). Accordingly, it can be hypothesized that the direct effect is significant in this model, the indirect effect mediated by discrimination is significant, the indirect effect mediated by loneliness is not significant, and the chain-mediated indirect effect of discrimination and loneliness is significant.

Bootstrap method was used to test the mediating effect between physical activity and subjective well-being, setting Bootstrap sampling 3000 times to estimate the total and indirect effects. As seen in Table 5, the indirect effect mediated by discrimination was 0.033 (95% CI = [0.006, 0.083]), the indirect effect mediated by loneliness was 0.029 (95% CI = [-0.025, 0.088]), and the indirect effect mediated by both discrimination and loneliness was 0.052 (95% CI = [0.014, 0.100]), with the total indirect effect was 0.113 (95% CI = [0.044, 0.183]). MacKinnon has noted in his work that there is evidence to support an indirect effect when the confidence interval excludes the value 0 [40]. The results showed that the mediating role of discrimination in physical activity - discrimination - subjective well-being was significant, loneliness in physical activity - loneliness - subjective well-being, discrimination and loneliness in physical activity - discrimination - loneliness - subjective well-being, the mediating role of the chain was significant, physical activity - discrimination - loneliness - subjective well-being, and loneliness - subjective well-being. -subjective well-being, the chain mediating role of physical activity was significant, and physical activity was significant in the direct role of physical activity-subjective well-being.

Discussion

The enhancement of rural left-behind children's subjective well-being is of great significance in promoting their physical and mental health, maintaining a good state of mind, and reducing negative emotions, which is closely related to their adherence to an appropriate amount of physical exercise. There are many cases in the existing literature on the study of "physical activity affects subjective well-being", but there is a lack of evidence and accumulation of analysis of the specific effects and the existence

Table 3 Descriptive statistics and correlation analysis of total scores for each variable ($n = 403$)

Variables	M \pm SD	PA	LS	PE	DP	L
PA	22.01 \pm 19.10	1.000				
LS	4.11 \pm 1.38	0.197**	1.000			
PE	3.09 \pm 0.73	0.230**	0.624**	1.000		
DP	1.84 \pm 0.70	-0.132**	-0.296**	-0.430**	1.000	
L	2.16 \pm 1.01	-0.157**	-0.481**	-0.646**	0.496**	1.000

* $p < 0.05$, ** $p < 0.01$

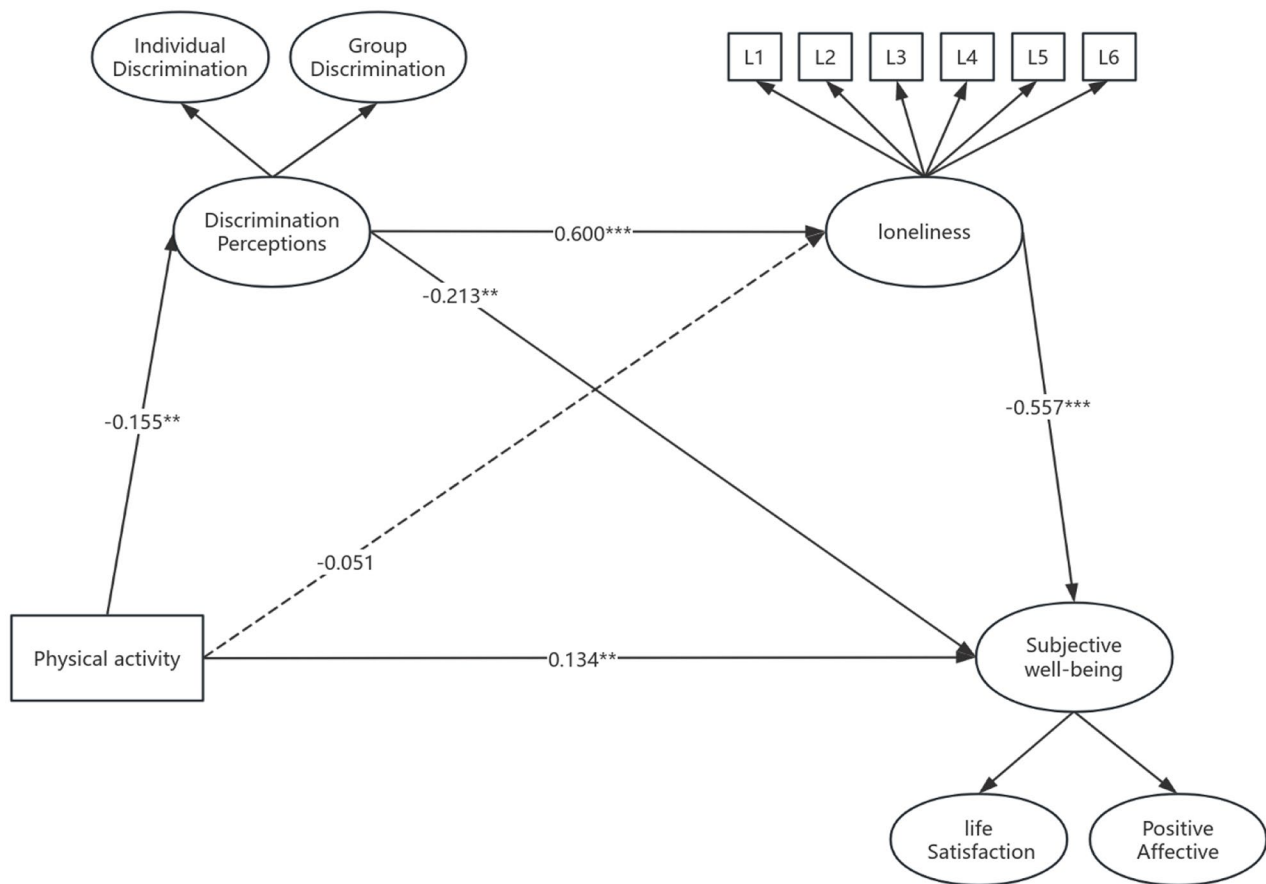


Fig. 1 A mediating model of the influence of physical exercise on subjective well-being of left-behind children. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 The significance of the relationships between the variables in the pathway

Variables effect relationship	β	Lower 2.5%	Upper 2.5%
PA→SWB	0.134	0.060	0.213
PA→DP	-0.155	-0.264	-0.033
DP→SWB	-0.213	-0.368	-0.051
PA→L	-0.051	-0.147	0.052
L→SWB	-0.557	-0.698	-0.401
DP→L	0.600	0.478	0.717

Table 5 Decomposition of mediation effects

Effect path	β	Lower 2.5%	Upper 2.5%
PA→SWB	0.134	0.060	0.213
PA→DP→SWB	0.033	0.006	0.083
PA→L→SWB	0.029	-0.025	0.088
PA→DP→L→SWB	0.052	0.014	0.100
Total effect	0.247	0.146	0.340
Total indirect effect	0.113	0.044	0.183

of mediating and moderating effects. In this paper, from the perspective of left-behind children in rural areas, we choose the perception of discrimination and loneliness in the group of left-behind children and use negative emotion as a mediating variable to explore the potential mechanism of physical exercise affecting the subjective well-being of left-behind children in rural areas.

This study showed that the beta value between physical activity and subjective well-being of the left-behind children was 0.134 (95% CI = [0.060, 0.213]), indicating that physical activity positively affects subjective well-being.

Relationship between physical exercise and subjective well-being

Previous observational and experimental studies on the relationship between physical exercise and subjective well-being have provided evidence of a positive correlation between the two, and the results of this study indicate that the direct effect of physical exercise and subjective well-being of rural left-behind children is significant, and hypothesis 1 is valid that participation in physical exercise can improve the well-being of the general population [41]. Previous studies have looked at

physical activity and mood and found that regular participation in physical activity produces a positive mood [42–44]. There are also studies demonstrating the important link between physical activity and life satisfaction, i.e., participation in physical activity can lead to higher quality of life and life satisfaction [45]. This is consistent with the results of this paper. In addition, physical activity can have an impact on subjective well-being through mediating variables such as physical self-esteem, interpersonal relationships, and personality, in addition to direct subjective well-being [46].

The mediating role of discrimination perception

Discrimination perception can mediate the relationship between physical activity and subjective well-being, its mediating effect value was 0.033 (95% CI = [0.006, 0.083]), which indicates that discrimination perception may be a risk factor for subjective well-being, which is consistent with the findings of previous research on the influencing factors of subjective well-being, and Hypothesis 2 is established. Goffman considers discrimination as a social attribute or characteristic that brings a sense of humiliation to a person, which is specifically manifested in looking down on the abilities and origins of him or her, such as meanness in attitude, psychological rejection, and behavioral alienation [47]. While rural left-behind children seem to be similarly labeled by the outside world, left-behind children when faced with the lack of family structure in most cases, the difficulties will encounter in terms of learning, psychology, health, and safety, as well as the presence of external pressures and questions, the discriminatory pressures may affect the health through silence, which equips them with a high level of threat assessment and vigilance, which can lead to a stressful reaction [48]. Being part of a social group but suffering special treatment means that higher levels of depression, higher levels of distress, and lower levels of self-esteem happen to them [49]. On the one hand, higher levels of individual discrimination are associated with lower levels of state self-esteem [50], on the other hand, self-esteem and affect are important components of the subjective evaluation of the quality of life in youth and these factors may be positively influenced by physical activity and cognitive-emotional factors [51]. In conclusion, physical exercise is an indirect way to increase the subjective well-being of rural left-behind children by enhancing their self-esteem and lowering their stress to contribute to making discrimination less influential on them.

Mediating role of loneliness

Page & Tucker (1994) found that loneliness was associated with lower levels of physical activity among elementary (grades 1–6), high school (grades 9–12), and college students [52]. Previous research on the

relationship between loneliness and physical activity has had mixed results, with several studies finding no association [53–55]. Mishra et al.'s study of female seniors showed that female seniors with high levels of loneliness had lower subjective well-being [56]. In this study, loneliness had a significant -0.557 (95% CI = $[-0.698, -0.401]$) beta with subjective well-being, whereas physical activity had a non-significant -0.051 (95% CI = $[-0.147, 0.052]$) beta with loneliness, the regression paths between physical activity and loneliness were not significant, which resulted in the fact that loneliness did not directly mediate between physical activity and subjective well-being, and Hypothesis 3 was not valid. The reason for this is hypothesized that discrimination perception plays a fully mediating role between physical activity and loneliness in the model, resulting in loneliness not playing a direct mediating role between physical activity and subjective well-being. It is hypothesized that discrimination perceptions are more likely to induce negative emotions in left-behind children than loneliness in rural left-behind children, thus affecting subjective well-being.

Chain mediating role of physical activity in positively predicting subjective well-being

This study showed that discrimination perceptions mediated between physical activity and loneliness in the chain mediation pathway between physical activity and subjective well-being. Perception of discrimination is significantly and positively related to the beta value of loneliness 0.600 (95% CI = $[0.478, 0.717]$), which is consistent with the study by Zhang Yihan et al., indicating that discrimination perception as a prominent psychological problem plays an inescapable role in the formation and promotion of loneliness, and loneliness is more likely to occur in the presence of discrimination, which is a risk factor for loneliness. Research shows that in the chain mediation path between physical exercise and subjective well-being, loneliness does not play a direct mediating role between physical exercise and subjective well-being, but plays an indirect mediating role between physical exercise and subjective well-being, and some scholars have pointed out that when an individual perceives discrimination from his peers or the outside world, he will be hesitant to socialize with other people, which will lead to the formation of the emotional experience of loneliness [25], and when left-behind children have discrimination from peers or the outside world, they will be more likely to develop loneliness. On the other hand, when left-behind children have a discrimination perception from the surrounding environment, the long-distance, long-term non-face-to-face parent-child communication makes parents unable to detect adolescents' inner troubles promptly, which makes adolescents' important psychological resources to cope with the pressure of

external discrimination are missing or reduced, and thus more feelings of loneliness will be generated [57]. In summary, it can be seen that discrimination perception is an important risk factor for loneliness, and the creation of discrimination perception is more capable of triggering negative emotions such as loneliness.

The chain mediating role of discrimination perception and loneliness in the positive effect of physical activity on subjective well-being was verified by the Bootstrap method, and hypothesis 4 was established. The constructed chain mediation model provides a new perspective for further advancing and understanding the relationship between physical activity and subjective well-being in the future. Physical activity can either directly positively affect subjective well-being or indirectly affect subjective well-being through discrimination perceptions and loneliness. The results support the psychological elasticity theory [58], indicating that physical activity can stimulate the psychological elasticity of rural left-behind children, bring energy to the left-behind children, enable the left-behind children to cope with the adaptive problems due to the lack of parental accompaniment more effectively and reduce the emergence of the negative emotions such as discrimination perception and loneliness, which will then weaken the negative impact on the subjective well-being. Left-behind children can bring about healthy physical gains through physical exercise, which enhances their physical fitness and contributes to their physical growth and development in adolescence; on the other hand, physical exercise can cultivate left-behind children's interest in physical exercise, reduce the negative impacts of perceptions of discrimination and loneliness, and help them better integrate into their classmates, thus improving their sense of well-being.

Research implications

How to enhance the subjective well-being of rural left-behind children and eliminate more negative emotions is a long way to go for rural educators in China. This study suggests that physical exercise can empower rural left-behind children to enhance their subjective sense of well-being and to effectively improve and take into account the psychology of left-behind children, to shape a healthy and complete personality for left-behind children, we should pay attention to the diversified value of the physical exercise.

In terms of practical implications: (1) The findings of this paper can provide a reference direction for rural schools on how to design physical education programs to more effectively improve the subjective well-being of rural left-behind children. For example, more interactive and interesting physical activities can be designed to reduce their sense of isolation while enhancing their

social skills and teamwork. (2) The results of the study emphasize the importance of physical exercise in improving the mental health of rural left-behind children, which provides new ideas for rural schools to carry out mental health education. Schools can incorporate mental health elements into physical education courses to help children correctly understand and deal with their negative emotions and improve their emotional regulation ability. (3) In addition, schools and families should strengthen communication and pay joint attention to the mental health of left-behind children to provide them with a healthier and more harmonious growing environment.

In terms of policy implications: (4) It can provide a direction for the government's future policy designation to encourage schools to carry out colorful sports activities to enhance the subjective well-being of rural left-behind children. For example, financial support can be provided to help schools build and optimize sports facilities and venues, and bring in sports teachers and coaches. (5) The government can also optimize the allocation of educational resources to ensure that left-behind children can enjoy the same educational resources and opportunities as urban children. At the same time, it can increase the investment in education in rural schools, raise teachers' salaries, and improve the teaching environment. (6) The government can promote the popularization of mental health education so that more people will understand and pay attention to the mental health problems of left-behind children. Organize experts to conduct mental health lectures to improve schools' and parents' understanding of and ability to deal with left-behind children's mental health problems. (7) The government can further improve its policy of caring for left-behind children and provide them with more support and assistance. It can strengthen economic assistance to their families, provide more social resources and public services, and reduce their economic pressure and psychological burden.

Limitations

This study has some limitations that need to be stated. First, this paper adopts a cross-sectional design of research, which cannot prove causality. Second, as a source of data for the study of rural left-behind children, this study relied solely on self-report questionnaires, which means that the data are more likely to have subjective judgments. Future research will use more objective measurements or collect data several more times to study the lag effect and causality more clearly.

Conclusion

This research is of great significance for the study of left-behind children. It reveals that physical exercise has a direct influence on the subjective well-being of rural left-behind children and also discovers that it has an indirect

effect through influencing discrimination perception, loneliness and the chain mediation of both. Except for the path through loneliness, which is not significant, the others are all significant. This research provides key basis and direction for improving the psychological conditions of left-behind children, highlights the importance of physical exercise, contributes to the formulation of relevant policies and practical guidance, and is of great practical significance for enhancing the well-being of left-behind children.

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Author contributions

F-Z.Feng, T Zhang: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Writing—original draft; H-Y.Li: Formal analysis, Supervision,. All authors have read and agreed to the published version of the manuscript.

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Data availability

In this study, the original data can be further consulted to the corresponding author.

Declarations

Ethics approval and consent to participate

All methods were performed in accordance with the relevant guidelines and regulations. The study protocol was approved by the ethics committee of Wuhan Sports University. Written informed consent to participate in this study was provided by the participant's legal guardian/next of kin.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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