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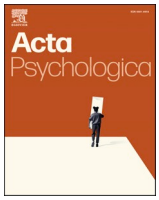

Influence of grit on adolescents' exercise adherence: The mediating role of exercise self-efficacy and the moderating role of self-control

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ABSTRACT

To investigate the impact of grit on adolescents' exercise adherence, the mediating role of exercise self-efficacy and the moderating role of self-control, stratified cluster random sampling was used to select 811 adolescents from three middle schools in Fujian Province, China. The results showed that grit was significantly positively correlated with exercise adherence and exercise self-efficacy ($r = 0.404$, 0.492; $p < 0.01$); exercise self-efficacy was also significantly positively correlated with exercise adherence ($r = 0.382$, $p < 0.01$); in the relationship between grit and exercise adherence, exercise self-efficacy played a mediating role, with an effect value of 0.118, accounting for 29.21 % of the total effect value (0.404); self-control moderated the predictive effect of grit on exercise adherence. Accordingly, for individuals with high levels of self-control, grit has a stronger predictive effect on exercise adherence. Therefore, it is recommended to improve adolescents' exercise adherence by strengthening their grit, enhancing their exercise self-efficacy, and improving their self-control ability.

1. Introduction

The World Health Organization (WHO) recommends that adolescents should engage in moderate-to-strenuous physical activity for at least 60 min per day (World Health Organization, 2010). Appropriate exercise engagement can significantly predict the individual's mental health, physical health, academic achievement, social skills, etc. (Chow et al., 2022; Smith & Merwin, 2021). However, the proportion of adolescents achieving this goal is far below the ideal level. Previous research results show that adolescents currently have insufficient exercise engagement, resulting in problems such as poorer eyesight and physical skills, and many adolescents have not formed the habit of exercise (Kuldavletova et al., 2021; Teare & Taks, 2021). Therefore, how to enhance adolescents' exercise adherence is an important issue to be solved for promoting their development.

As a key concept in the domain of psychology, grit has received widespread attention in recent years from fields including education, career development and mental health research. “Grit” involves two core dimensions: one is the continuous pursuit of long-term goals without the idea of giving up even in the face of difficulties and challenges; the other is the lasting commitment to interest and passion, which can ensure an unchanged focus and enthusiasm for a certain field for a long time (Oshio et al., 2018). From the perspective of developmental psychology, adolescence is a vital period for individuals to form personalities and an important stage for them to cultivate and strengthen their grit. During this period, adolescents are at a critical stage of identity exploration, self-identity construction and social skill training. Their behavioral habits, values and coping strategies have a profound impact on their future academic achievements, career development and overall quality of life (Nisar et al., 2020). It has been found that adolescents with higher levels of grit may have stronger intrinsic motivation for physical activity, and can derive pleasure and satisfaction from exercise, thus getting a positive emotional experience that in turn works as a powerful driving force for their continued participation in exercise (Hein et al., 2021). Besides, in response to challenges and failures during exercise, gritty adolescents would demonstrate stronger tenacity and not easily give up, but overcome obstacles by adjusting strategies, increasing efforts or seeking support and thereby achieve personal goals (Cormier et al., 2021). Grit also enables adolescents to perform well in time management and self-regulation and allows them to effectively balance academic, social and other life needs, thus shaping exercise as an indispensable part of their daily lives (Marentes-Castillo et al., 2022).

Exercise self-efficacy is one of the core concepts of social cognitive

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theory, reflecting an individual's confidence in his ability to perform specific behaviors to obtain expected results (Medrano-Ureña et al., 2020). In the context of exercise, exercise self-efficacy specifically refers to an individual's belief in his ability to complete physical activity of a certain intensity and duration, whether in a stress-free environment or in the face of challenges and adversity. This belief not only affects the individual's exercise decisions and behaviors, but is also closely related to his exercise adherence, physical adaptability and psychological well-being (Medrano-Ureña et al., 2020).

It has been found that adolescents with high-level grit tend to set and pursue long-term goals, and do not easily give up even when faced with difficulties (Verner-Filion et al., 2020). On the one hand, this process requires not only the persistent pursuit of goals, but also the individual's confidence in his own ability, that is, high exercise self-efficacy. On the other hand, when adolescents believe that they have the ability to overcome all obstacles during exercise, they are more likely to not give up easily when faced with setbacks, but instead seek ways to solve the problems and continue to adhere to the exercise plan. Hence, the improvement of adolescents' exercise self-efficacy further enhances their exercise adherence (Medrano-Ureña et al., 2020).

As an important component of individuals' psychological function, self-control refers to one's ability to align his thoughts, emotions and behaviors with long-term goals rather than immediate impulses. Self-control covers multiple layers, including attention control, emotion regulation, impulse suppression and goal-oriented behaviors (Duckworth & Gross, 2014). When faced with temptation, pressure or adversity, high-level self-control enables individuals to adhere to goal-oriented behaviors, resist interference and maintain focus and perseverance, so that it becomes a key factor for individuals to achieve personal goals and maintain physical and mental health (Şimşir Gökalp, 2023). Self-control may be a moderating variable between grit and exercise self-efficacy, as well as between grit and exercise adherence. Its role is mainly reflected in its moderating effect on the relationship between grit and exercise self-efficacy. When individuals have a high level of self-control, grit has a more significant positive predictive effect on exercise self-efficacy. Individuals with high self-control work better in managing their emotions and behaviors, and effectively focus their attention on their goals. Even when facing difficulties and challenges, they can remain calm and focused, so that they are more likely to accumulate successful experiences and enhance their exercise self-efficacy (Wennerhold & Friese, 2023).

Based on the research findings above, a moderated mediating model (as shown in Fig. 1) was constructed to examine the relationships among grit, exercise self-efficacy, exercise adherence and self-control.

Although previous studies have focused on the potential connections among grit, exercise adherence, exercise self-efficacy and self-control, how these variables interact with each other remains unresolved. The moderated mediating model constructed in this study aimed to probe into the interaction between “grit” and “exercise adherence”. In-depth analysis was performed on the interactions among these psychological variables to examine the mediating effect of exercise self-efficacy and the moderating effect of self-control. The results of this study can fully demonstrate the psychological mechanism through which exercise adherence is formed in adolescents, shape a solid scientific basis for designing more accurate and effective exercise schemes, and provide theoretical guidance and practice implications for promoting the sustainability and optimization of sports behaviors.

2. Participants and methods

2.1. Participants

According to the experience of previous researchers, a large-scale sample survey is generally statistically required to have a sample size of 5–10 times the number of items, with a total of 57 items in the scales, in order to ensure the representativeness of the sample. Besides, considering rejection to fill in the questionnaire, invalid copies of the questionnaire and sampling errors, the sample size should be expanded by 20 %, so that the calculated sample size should not be <684. According to the definitions of adolescents in adolescent psychology and exercise physiology (Duckworth & Quinn, 2009; Si, 2010), individuals aged 12–18, namely middle and high school students, were selected as the survey participants. In line with the principle of stratified cluster sampling, adolescents aged 12–18 were selected from three middle schools in Fujian Province, China for investigation. The survey was conducted from May to July 2024, with 823 copies of the questionnaire distributed and 811 valid copies, resulting in an effective response rate of 98.54 %. The participants included 392 boys and 419 girls aged between 12 and 18 years old, with an average of 14.83 ± 1.92 years old. Permission was obtained from each participant before the survey, and all the participants took part in this study voluntarily. Permission was also obtained from relevant school administrators and head teachers. This study was approved by the Ethics Committee of Fuzhou Polytechnic.

2.2. Tools

2.2.1. 12-Item Grit Scale

12-Item Grit Scale, which was formulated by Duckworth and Quinn (2009) and translated into Chinese by Xie et al. (2017), was used in this study. The scale consists of 12 items and adopts Likert 5-point scoring, with 1 indicating “completely agree” and 5 indicating “completely disagree”. The scale covers two dimensions: interest stability and effort persistence. It includes items such as “I have overcome big challenges in the past” and “My interest in doing things is constantly changing”. The 6 items related to interest stability are reversely scored. A higher total score means that the participant has more outstanding grit. The Cronbach's a coefficient of the total scale is 0.895, and the Cronbach's a coefficients in the dimensions of effort persistence and interest stability are 0.801 and 0.708, respectively. This scale has been proven to have good reliability and validity in the Chinese adolescent population (Song et al., 2021).

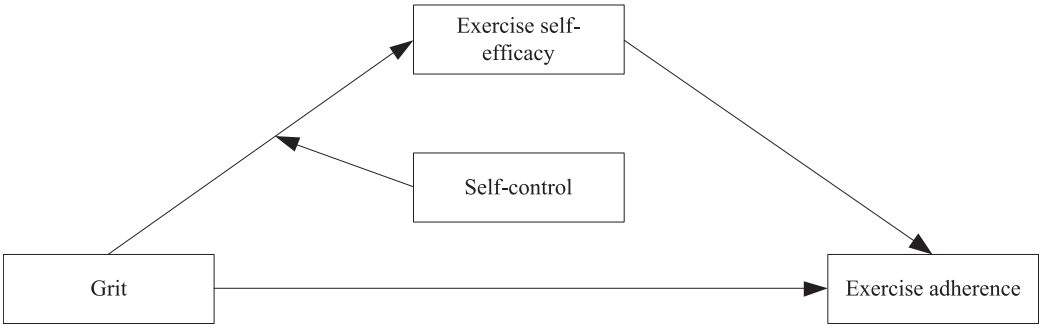

Fig. 1. A moderated mediating model.

2.2.2. Exercise adherence scale

Exercise Adherence Scale formulated by Chinese scholars Wang et al. (2016) was used in this study. It has three sub-dimensions: effort input, emotional experience and behavioral habit. The scale includes items such as "I participate in physical activity for at least 1 hour each time", "I work hard to practice new skills to improve myself', and "I often feel positive and uplifted after exercise". The scale consists of 14 items, and uses Likert 5-point scoring. The final total score is calculated as the sum of scores in all items. A higher final score indicates stronger exercise adherence. The internal consistency coefficient of all dimensions is between 0.87 and 0.92, confirming that the scale has good reliability and validity.

2.2.3. Self-control scale

Self-control Scale (SCS) revised by Tan and Guo (2008) was adopted in this study. The scale covers five dimensions: healthy habits, moderate entertainment, temptation resistance, focused working and impulse control. It includes items such as "Waking up in the morning is a difficult thing for me", "I spend too much money", "Everyone says I have iron willpower", "I have difficulty in concentrating my mind", and "I am too prone to losing my temper". The scale consists of 19 items and uses 5-point scoring, with 1 indicating "completely disagree" and 5 indicating "completely agree". A higher score in each dimension indicates better self-control. 4 items are scored positively, while the rest are scored reversely. The Cronbach's α coefficient of this scale is 0.885.

2.2.4. Exercise self-efficacy scale

The Chinese version of Exercise Self-Efficacy Scale formulated by Marcus et al. (1992) was used to measure exercise self-efficacy in this study (Zhang, 2014). This scale involves four dimensions: mental distress, physical activity disorders, conflict of affairs and physical discomfort. It includes items such as "When I feel tired", "If I fail to reach my exercise goals", "When I have too much work to do", "When I feel uncomfortable while exercising", etc. The scale consists of 18 items and uses Likert 5-point scoring, with 1 indicating "definitely impossible" and 5 indicating "definitely possible". A larger total score indicates more confidence in participating in exercise. The internal consistency validity of this scale is 0.87; its split-half reliability is 0.90; its test-retest reliability is 0.83.

2.3. Statistical methods

The following methods were mainly adopted in this study for data statistics and analysis. Firstly, SPSS26.0 software was used to test the reliability of the measurement tools. Secondly, SPSS26.0 was used for descriptive statistical analysis and correlation analysis. Thirdly, significance test of difference was used to determine whether the difference between different gender groups in each variable was significant. Fourthly, the interactions among grit, exercise adherence, exercise self-efficacy and self-control were examined using SPSS26.0 PROCESS macro model. A difference with $P < 0.05$ was considered statistically significant.

3. Results

3.1. Common method deviation testing

Firstly, to minimize the common method bias caused by the self-reported questionnaire method, the following actions were implemented: (1) Using validated measurement tools that have been proven to have good reliability and validity; (2) Procedural control was carried out through collecting multi-source data, emphasizing anonymity and ensuring confidentiality in the process of data collection; (3) Increasing the sample size as much as possible to reduce sampling errors and improve the representativeness of the research results. Then, Harman's single factor test was used to examine the effectiveness of procedural control. Exploratory factor analysis was conducted by grouping the four variables together. The results show that there were 8 factors with eigenvalues >1, and the explanatory power of the first factor was 21.78 %, <40 %. This indicates that the degree of common method variation in this study was within an acceptable range (Zhou and Long, 2004).

3.2. Descriptive statistics and correlation analysis

Pearson correlation analysis was performed to analyze the relationships among variables. The results are shown in Table 1. It can be seen that there was a significant positive correlation between grit and exercise adherence, with the correlation coefficient being 0.404 and $P < 0.01$. There was a significant positive correlation between grit and exercise self-efficacy, with the correlation coefficient being 0.492 and $P < 0.01$. There was a significant positive correlation between exercise self-efficacy and exercise adherence, with the correlation coefficient being 0.382 and $P < 0.01$. These results indicate that adolescents have higher exercise adherence when their grit and exercise self-efficacy are higher. In addition, self-control is positively correlated with grit, exercise self-efficacy and exercise adherence at a low significance level. The results of correlation analysis indicate that further hypothesis testing could be conducted on the data.

3.3. Gender differences

Independent sample t-test was performed to test the gender differences in the scores in each variable. The results showed that there were significant gender differences ($t = 3.98, 4.32, 2.236$, $P < 0.001$) in the variables including grit, exercise adherence and exercise self-efficacy, and boys tended to have significantly higher scores than girls. However, there was no significant difference in self-control between boys and girls.

3.4. Mediating effect

To test the mediating effect, linear regression was performed using Process3.4 plugin of SPSS26.0 under Model 4, where grit was the independent variable, exercise adherence was the dependent variable, and exercise self-efficacy was the mediating variable. All the variables were standardized. The regression coefficients obtained were standardized regression coefficients. The results are shown in Table 2.

From Table 3, it can be seen that the regression of grit on exercise adherence was significant, with the coefficient being 0.41 and $P < 0.001$. This indicates that adolescents have higher exercise adherence when their grit is higher. Hence, the main effect was verified. The regression of grit on exercise self-efficacy as the mediating variable was significant, with the coefficient being 0.49 and $P < 0.001$. This indicates that higher grit leads to higher exercise self-efficacy. After both exercise self-efficacy and grit were incorporated into the equation, the regression of exercise self-efficacy on exercise adherence was significant, with the coefficient being 0.239, and the regression of grit on exercise adherence was also significant, with the coefficient being 0.286, significantly lower than the direct predictive effect coefficient (0.404). In summary, the mediating effect, which was partial, of grit on exercise adherence through exercise self-efficacy was validated. The mediating effect was 0.118, 95 % CI and the confidence interval was [0.08, 0.15] excluding 0. Therefore, the mediating effect was significant.

Table 1
Analysis of correlation between variables.

	M	SD	1	2	3	4
1 Grit	32.94	12.16	1			
2 Exercise adherence	37.79	12.96	0.404**	1		
3. Exercise self-efficacy	47.43	17.18	0.492**	0.380**	1	
4 Self-control	47.79	17.89	0.290**	0.111**	0.257**	1

Table 2
Analysis of regression among variables.

Dependent variable	Independent variable	β	t	P	R	R^2
Exercise adherence	Grit	0.404	12.563	0.001	0.404	0.16
Exercise self-efficacy	Grit	0.492	16.072	0.001	0.492	0.24
Exercise adherence	Grit	0.286	7.953	0.001	0.452	0.21
	Exercise self-efficacy	0.239	6.649	0.001		

Table 3
Analysis of the mediating effect.

	Effect value	Standard error	Boot CI lower limit	Boot CI upper limit	Effect size
Total effect	0.404	0.03	0.001	0.341	100 %
Direct effect	0.286	0.04	0.002	0.215	70.79 %
Indirect effect	0.118	0.02	0.081	0.154	29.21 %

3.5. Moderating effect

To test whether the moderating effect of the first- and second-half path was valid, linear regression was performed using Process3.4 plugin of SPSS26.0 under Model 58, where grit was the independent variable, exercise adherence was the dependent variable, exercise self-efficacy was the mediating variable and self-control was the moderating variable. Interaction item 1 (self-control*grit) and interaction item 2 (self-control*exercise self-efficacy) were constructed. All the variables were standardized. The regression coefficients obtained were standardized regression coefficients.

From Table 4, it can be seen that the regression of grit*self-control on exercise self-efficacy (mediating variable) was significant, with the coefficient being 0.07 and $P < 0.001$. This indicates that self-control can moderate the relationship between grit and exercise self-efficacy. The research hypothesis was validated. To investigate how self-control moderated the first-half path, the participants were divided by self-control into a high-score group (+1 standard deviation) and a low-score group (−1 standard deviation). It was found that in the high-score group, the coefficient of regression of grit on exercise self-efficacy was 0.51; in the low-score group, the coefficient of regression of grit on exercise self-efficacy was 0.37. The decrease in the coefficient indicates that with the improvement of self-control, grit would have an increasingly stronger impact on exercise self-efficacy. The details are shown in Fig. 2.

The moderated mediating effects obtained when the moderating variable self-control was at different levels are shown in the table below. The moderated mediating effect was 0.12 in the high self-control group and 0.09 in the low self-control group. There was a significant difference between the two groups ($P = 0.016$, 95CI [0.01, 0.03]), indicating that the moderated mediating effect was validated.

Table 4
Analysis of the moderating effect.

Dependent variable	Independent variable	β	t	P	R	R^2
Exercise self-efficacy	Self-control	0.10	3.07	0.020	0.51	0.26
	Grit	0.44	13.91	0.001		
	Interaction Item 1	0.07	2.38	0.017		
Exercise adherence	Grit	0.29	7.95	0.001	0.45	0.21
	Exercise self-efficacy	0.24	6.64	0.001		

4. Discussion

4.1. Scores and differences in each variable

It was found in this study that there were significant positive correlations among the four variables: grit, exercise self-efficacy, exercise adherence and self-control. This indicates that these four factors have complex interactions and mutual influences, and that grit, exercise self-efficacy and self-control may be influencing variables of exercise adherence.

It was found in this study through independent sample *t*-test that boys and girls had significant differences in grit, exercise adherence and exercise self-efficacy, but had no significant difference in self-control. There may be multifaceted reasons for this phenomenon, including social and cultural backgrounds, educational environments and personal experiences (Lam & Zhou, 2022). Firstly, boys' score in grit was significantly higher than girls'. It has been found that men generally have higher scores than women in grit, which may be related to traditional social role expectations. In many cultures, men are encouraged to demonstrate strength, independence and grit, while women may be expected to show more empathy and affective expressions (Zhang, 2018). Meanwhile, the male brain is featured with more clear functional zoning (e.g., the right brain dominating the spatial ability), which may enhance their focus on the target; the female brain has stronger coordination between the left and right hemispheres, making girls better at multitasking but possibly dispersing their persistence towards a single goal. This partly explains the significant gender difference in grit observed in this study. Secondly, boys' score in exercise adherence was significantly higher than girls. Exercise adherence involves an individual's ability to continuously participate in physical activity. Men tend to have higher scores in this variable, possibly because society has higher expectations for male engagement in sports, or men are more inclined to choose competitive and high-intensity sports types (Zhao & Liu, 2023). At the same time, social mindset also has a certain influence on the stereotyping of men's body image. Men are often encouraged to shape their muscles and sense of strength through exercise, and the social and cultural admiration for “strong men” has become an important driving force for men to adhere to exercise. Thirdly, boys' score in exercise self-efficacy was significantly higher than girls'. Men's higher scores in this aspect may reflect their higher evaluation of their own ability (Eibl et al., 2020). Relevant research results show that testosterone levels make it easier for men to achieve short-term results in strength training (e.g., a decrease in body fat percentage and an increase in muscle size), thereby enhancing their confidence in their athletic abilities. Finally, there was no significant difference in the score in self-control between boys and girls, indicating that gender is not the determining factor in managing one's behaviors, emotions and impulses. Self-control ability relies more on the individual's willpower, goal setting ability and executive function rather than gender.

Although the statistical results of this study reveal gender differences in grit, exercise adherence and exercise self-efficacy, it should be recognized that these differences are affected by multiple factors and may change with time passage and socio-cultural changes. In response, education and policy makers should strive to create an inclusive and equal environment, encouraging all members to cultivate these important psychological traits without being limited by gender stereotypes. Examples include encouraging women to participate in challenging activities, adjusting family upbringing styles and helping women establish positive attribution patterns through cognitive training. These measures can promote the balanced development of personality traits between genders.

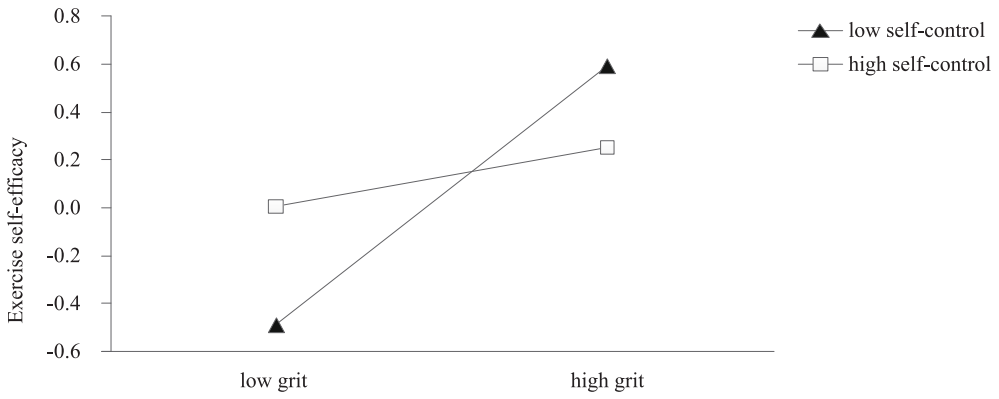

Fig. 2. Adjustment effect model diagram.

4.2. Impact of grit on adolescents' exercise adherence

It was found in this study that grit had a direct predictive effect on adolescents' exercise adherence. This indicates that higher grit can promote adolescents' exercise adherence, which is consistent with previous research findings (Rutberg et al., 2020). As Rutberg et al. (2020) found through a questionnaire survey and interviews with students and teachers, perseverance is the ideal goal for making physical activity interventions sustainable. The results of this study also support previous theoretical findings, such as growth mindset theory (Yeager & Dweck, 2020) and psychological capital theory (Youssef-Morgan & Luthans, 2013). Growth mindset theory emphasizes that individuals believe that their ability can be developed through hard work. Adolescents with grit often possess a growth mindset, viewing failures and challenges in exercise as opportunities to accelerate learning and growth. This mindset encourages them to persevere even in the face of setbacks (Wahidah & Royanto, 2021). Psychological capital consists of four components: hope, optimism, tenacity and self-efficacy. The trait of grit is closely related to psychological capital, as it enables adolescents to maintain optimism and hope for the future. Even if encountering difficulties during exercise, they can be resilient instead of easily giving up (Lee et al., 2022). This indicates that when designing an exercise plan for adolescents, sports programs that can enhance their adherence when facing challenges can be incorporated to strengthen their trait of grit.

4.3. Mediating role of exercise self-efficacy

It was found in this study that exercise self-efficacy mediated the predictive effect of grit on adolescents' exercise adherence. This indicates that the significant positive predictive effect of grit on adolescents' exercise adherence is to some extent mediated by exercise self-efficacy. Adolescents with stronger exercise self-efficacy are more willing to engage in exercise.

On the one hand, grit can boost up exercise self-efficacy, which is consistent with the findings obtained by Rafiee et al. (2022) from their research focusing on athletes. The results of this study also confirm previous theoretical findings, such as self-efficacy theory (Bandura, 1978) and self-determination theory (Deci & Ryan, 2012). The self-efficacy theory suggests that an individual's belief in their ability to complete a task is a key to achieving behavioral change. Due to their persistent pursuit of long-term goals and tolerance for difficulties, individuals with grit are more likely to accumulate successful experiences and positive feedback when facing challenges from exercise, directly enhancing their self-efficacy. The experience of successfully overcoming obstacles during exercise enhances their confidence in their ability, thereby improving their self-efficacy (Usher et al., 2019). Secondly, self-determination theory focuses on individuals' intrinsic and extrinsic motivation, as well as how to promote self-efficacy by satisfying basic psychological needs including autonomy, competence and belonging (Gao et al., 2021). Individuals with grit tend to experience autonomy and competence during exercise, which can enhance their self-efficacy and increase their likelihood to continue participating in exercise. On the other hand, self-efficacy can promote adolescents' exercise adherence. Emotion regulation theory suggests that how individuals manage and regulate their emotional state has a significant impact on their behaviors (Bosse et al., 2010). When facing setbacks during exercise, adolescents with high self-efficacy are more likely to adopt positive emotion regulation strategies, such as reassessing the conditions and seeking social support. This emotion regulation ability allows them to maintain a positive attitude, thereby promoting their exercise adherence (Beatty & Janelle, 2020; Bernstein & McNally, 2018). This suggests the needs to create a positive interactive environment during exercise, encourage teamwork and peer motivation through designs such as team sports (e.g. football and basketball), enhance the sense of belonging through cooperation and mutual encouragement, and use the successful experiences of peers to boost confidence, thereby improving adolescents' exercise self-efficacy.

4.4. Analysis of the moderating effect of self-control

It was found in this study that self-control played a moderating role and moderated the predictive effect of grit on adolescents' exercise adherence. This indicates that self-control can moderate the relationship between grit and exercise self-efficacy. A higher level of self-control results in a greater predictive effect of grit on exercise self-efficacy. This research result is basically consistent with the research results obtained by Briki (2020).

This phenomenon may be attributed to the following reasons. Firstly, individuals with strong self-control work better in effectively managing their behaviors, especially when faced with temptation or adversity, and are more able to adhere to goal-oriented behaviors (Adriaanse & Ten Broeke, 2022). This means that when individuals possess grit, their high level of self-control enables them to engage in exercise more consistently and gradually establish a strong confidence in their exercise ability, known as exercise self-efficacy. Secondly, self-control also covers effective management of emotions (Gagne et al., 2021). Faced with challenges and setbacks during exercise, gritty individuals with high self-control can regulate negative emotions more effectively and maintain a positive mindset. This emotional stability further enhances their self-efficacy during exercise. Thirdly, individuals with strong self-control are able to allocate their time and energy more reasonably (Zimmerman et al., 2023), and ensure their input of sufficient resources into exercise even when facing other life pressures. This resource management ability maximizes the positive effect of grit, thereby enhancing exercise self-efficacy.

The results of this study also underscore the amplification effect of high-level self-control. When individuals have a high level of self-control, they perform better in effectively overcoming obstacles

encountered during exercise, whether they are external environmental challenges or internal emotional fluctuations. This capability makes grit more effective in driving individuals to continuously engage in exercise, accumulate successful experiences and enhance self-efficacy. In the context of high self-control, individuals with grit are not only able to persist in exercise, but also fully engage in exercise each time and constantly challenge themselves. This experience of devoted participation and continuous progress greatly enhances their exercise self-efficacy. Moreover, the results of this study also support the viewpoint of self-regulation theory that self-control is a core component of self-regulation, involving how individuals manage their thoughts, emotions and behaviors to achieve goals (Lyngs et al., 2020). The results of this study indicate that self-control plays a moderating role between grit and exercise adherence, which is consistent with the view of self-regulation theory about the impact of self-control on behaviors.

In summary, self-control is a key psychological resource that can promote the connection between grit and exercise self-efficacy. This promoting effect is particularly significant especially when the level of self-control is high. By effectively managing behaviors, emotions and resources, self-control enables individuals with grit to achieve sustained success during exercise, thereby continuously enhancing their self-efficacy. This suggests that when guiding adolescents to engage in physical exercise, it is crucial to improve their self-control ability. For example, in physical education classes, phased goals can be set to make them perceive their progress, and more sports programs that require team collaboration (such as group competitions) can be designed.

5. Conclusions and recommendations

The results of this study show that grit can significantly predict exercise adherence; exercise self-efficacy plays a mediating role; self-control can moderate the predictive effect of grit on exercise adherence. Specifically, for individuals with high-level self-control, grit has a stronger predictive effect on exercise adherence. This indicates the possibility of improving adolescents' exercise adherence in three aspects: 1) strengthening grit, for example, by designing and implementing targeted educational programs, and educating adolescents to learn and develop grit with the help of real-life examples; 2) enhancing exercise self-efficacy, for example, through systematic sports skills training which allows adolescents to accumulate successful experiences in mastering sports skills; and 3) improving self-control, for example, by educating adolescents to monitor themselves with tools such as log recording and applications, set short-term and long-term exercise goals, learn to plan time reasonably, and enhance self-control through self-motivation or reward and punishment mechanisms.

6. Limitations and prospects

The results of this quantitative study reveal, to some extent, the complex relationships among grit, exercise self-efficacy, self-control and exercise adherence. However, due to the limitations of the cross-sectional design used in this study, despite the finding of significant correlations among variables, the essence of causal relationships has not been captured, resulting in the failure to fully understand how these psychological traits dynamically affect exercise adherence.

In future research, longitudinal or follow-up study designs can be used to explore how factors such as grit and self-control affect the development trajectory of exercise self-efficacy and exercise adherence over time; Long-term observation of the impact of these psychological characteristics on changes in exercise habit can provide more solid data support for formulating exercise strategies. In addition, the sampling of adolescents from two middle schools in Fujian Province, China in this study was unable to include a broader range of participants, leading to certain limitations. In future research, efforts should be made to observe and examine more adolescents from different developmental stages and cultural backgrounds. In summary, intervention plans can be designed based on the results of this study and implemented to enhance grit, self-control and exercise self-efficacy. The effectiveness of these intervention measures in improving exercise adherence should be evaluated. The theoretical research results should be transformed into practical applications to expand the application value of this study.

CRediT authorship contribution statement

Liping Dai: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bingjin Su:** Writing – original draft, Methodology, Conceptualization. **Qiang Liu:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Ethical considerations

This study was approved by the Fuzhou Polytechnic ethics committee (20231201).

Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

Data will be made available on request.

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