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Effects of site type in physical education courses on changes in grit and exercise addiction among college students: a comparative quasi-experimental study

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Abstract

Objective: This study aimed to examine the effects of physical education courses in different settings on the development of grit and the mitigation of exercise addiction tendencies among college students, and to further compare the relationship between changes in grit and changes in exercise addiction.

Methods: A pre–post quasi-experimental design was adopted. A total of 818 undergraduate students from seven universities in Wuhan, China, participated in the study, including 563 male and 255 female students. According to the type of course setting, participants were divided into an open natural setting group (N = 213) and a strictly site-constrained group (N = 605). Grit was assessed using the Original Grit Scale (Grit-O), and exercise addiction was measured using the Exercise Addiction Inventory (EAI) at the beginning and end of the semester.

Results: The open natural setting group showed more favorable changes in the grit total score, persistence effort, and EAI score. Repeated-measures analysis of variance showed significant time × site type interaction effects for the grit total score, persistence effort, and EAI score, all at $p < 0.001$, whereas the interaction effect for interest consistency was not significant. Simple-effects analyses indicated that the open natural setting group showed significant increases in the grit total score and persistence effort, together with a significant decrease in EAI score. In contrast, no significant pre–post changes were observed in the strictly site-constrained group. Correlation analyses showed that, in the total sample, changes in EAI score were significantly and negatively correlated with changes in the grit total score and persistence effort. Subgroup analyses further indicated that these negative associations were mainly observed in the open natural setting group, whereas in the strictly site-constrained group, changes in interest consistency were significantly and positively correlated with changes in EAI score. Regarding sex differences, females in the open natural setting group showed significantly greater changes in interest consistency than males ($p = 0.037$).

Conclusion: Site type may be an important contextual condition influencing changes in grit and exercise addiction among college students. Compared with strictly site-constrained courses, courses delivered in open natural settings were more likely to be accompanied by increases in the grit total score and persistence effort, as well as a more favorable decreasing trend in exercise addiction. Moreover, the relationship between changes in grit and changes in exercise addiction differed across course site types.

Keywords: grit; exercise addiction; site type; outdoor education; college students

1. Introduction

With the accelerating pace of modern life and increasing psychological stress, mental health problems among college students have attracted growing scholarly attention. Physical exercise is an important pathway for promoting mental health (Nguyen et al., 2023a; Wolf et al., 2024; Huang et al., 2025; Wang et al., 2025) , and physical activity interventions have been shown to improve mental health and to be associated with lower levels of depression among college students (Huang et al., 2024; Li et al., 2025a) . Regularized team sports with clearly defined site boundaries also have mental health benefits, possibly through psychosocial mechanisms such as structured activity, peer interaction, and a sense of team belonging(Easterlin et al., 2019) . Increasing evidence suggests that exposure to nature and outdoor physical activity can provide additional psychological benefits, including improved emotional recovery, psychological well-being, and subjective health(Singh et al., 2023; Dawes et al., 2024) . Therefore, "where a course is delivered" is not a neutral background condition, but may be an important factor shaping the psychological effects of physical education courses (Buckley et al., 2024).

Grit, as an important non-cognitive factor for predicting long-term individual achievement, was proposed(Duckworth et al., 2007) and consists of two dimensions: persistence effort and interest consistency. Although its structural validity, overlap with conscientiousness, and cross-context applicability remain debated, this two-dimensional framework continues to represent the dominant empirical approach in current research (Duckworth and Gross, 2014; Credé et al., 2017) . Existing studies have shown that grit is not entirely stable, but may change with developmental experiences, goal commitment, and educational environments(Jiang et al., 2019) . Research in sport and challenging contexts has also indicated that grit is associated with athletic performance, athlete well-being, and sustained engagement, suggesting that the task characteristics of a course may influence the development of grit(Cormier et al., 2024).

However, the cultivation of grit through courses does not necessarily imply wholly positive outcomes, because sport participation may also be accompanied by risks such as overtraining, compulsive involvement, functional impairment, and exercise addiction; these potential psychological costs should not be overlooked (Di Lodovico et al., 2019a) . Vulnerability to exercise addiction may vary across sport types and sport cultures, and team sports as well as highly committed competitive cultures may also entail such risks (Di Lodovico et al., 2019b) . Exercise addiction is commonly identified and measured using the Exercise Addiction Inventory, a standardized tool with good brevity and practical applicability(Griffiths et al., 2005a).(Claussen et al., 2024) further noted that high frequency, high intensity, and strong identification with exercise should not automatically be interpreted as "the more, the better," because for some individuals, exercise may shift from a health-promoting behavior to an imbalanced behavior characterized by addictive features. Therefore, if studies only examine how courses enhance grit without simultaneously considering whether they are accompanied by changes in exercise addiction risk, the overall educational value of physical education courses may be overestimated (Weinstein and Szabo, 2023; Chhabra et al., 2024).

From the perspectives of classroom ecology and constraints-led pedagogy, site boundaries, rule structures, and environmental uncertainty in physical education courses are not merely external conditions, but important contextual constraints that shape students' behavioral organization, task engagement, and psychological experiences (Rudd et al., 2021) . Courses delivered in open natural settings place greater emphasis on uncertainty, environmental adaptation, risk judgment, and real-time adjustment. Existing research has shown that outdoor challenge activities can enhance self-efficacy and psychological growth (Singh et al., 2023) , but highly motivational qualities do not necessarily translate into better outcomes in all contexts (Tyne et al., 2024) . This suggests that different course sites may not only alter modes of participation, but also reshape the psychological mechanisms activated by the course.

Nevertheless, several important gaps remain in the existing literature. First, most studies have focused primarily on the effects of individual traits on grit and exercise addiction, while paying insufficient attention to environmental factors. Second, research on grit has often been limited to a single positive outcome, with few studies simultaneously incorporating potential risk indicators such as exercise addiction. Third, previous studies have mostly discussed outdoor challenge programs, with outcomes primarily pointing to self-efficacy and psychological growth, whereas few have directly examined the effects of site type on the coupled changes in grit and exercise addiction. The innovation of the present study lies mainly in three aspects. First, rather than classifying courses according to educational concepts, this study defines course ecology in terms of "strictly site-constrained" and "open natural setting" characteristics. Second, while examining grit, it also incorporates exercise addiction as a potential risk outcome. Third, beyond analyzing the grit total score, it further distinguishes between changes in persistence effort and interest consistency.

Based on this rationale, the present study defines two types of course ecology—strictly site-constrained courses and open natural setting courses—and simultaneously examines pre–post changes in grit, persistence effort, interest consistency, and exercise addiction among college students. It further analyzes the relationship between changes in grit and changes in exercise addiction.

2. Methods

2.1 Course setting

This study was conducted in the context of university physical education courses and compared the effects of courses delivered in different site types on changes in grit and exercise addiction among college students. The courses were classified into two categories. The first category comprised courses delivered in open natural settings, mainly including mountaineering, outdoor outward-bound training, and wilderness survival. These teaching activities were primarily conducted in mountainous areas, forested areas, and other open natural environments in Wuhan, China. The second category comprised strictly site-constrained courses, mainly including ball sports with clearly defined rules, fixed boundaries, and standardized site requirements, such as football, basketball, volleyball, badminton, table tennis, tennis, and pickleball. Both types of courses were implemented over a full semester lasting 16 weeks. Each class

lasted 90 minutes, with a 5-minute break. Each class was taught by one instructor and included 25–40 students.

2.2 Participants

A total of 904 college students were initially recruited. Of these, 818 students completed all assessments, including 605 students in the strictly site-constrained group, with 419 males and 186 females, and 213 students in the open natural setting group, with 144 males and 69 females. Eighty-six students withdrew from the study for the following reasons: 51 withdrew because of course changes, such as scheduling conflicts with other courses; 17 were absent from two or more teaching sessions; 14 were unable to continue participating because of illness; and 4 withdrew without providing a reason. The inclusion criteria were as follows: (1) undergraduate students aged 18–25 years; (2) being physically healthy and actually participating in the corresponding physical education course; (3) having the ability to independently complete the course activities and questionnaire assessments; and (4) completing the scales at both the pretest and posttest time points. The exclusion criteria were as follows: (1) inability to complete the course because of injury, illness, prolonged absence, or other special circumstances; (2) failure to complete either the pretest or posttest scales; and (3) obviously invalid questionnaire responses or failure in response matching. All data were anonymized to protect the privacy of each student. Participants were provided with informed consent information before the study and were allowed to withdraw at any time without any consequences. This study was approved by the Ethics Committee of China University of Geosciences (Wuhan).

2.3 Study procedure

This study adopted a pretest–posttest quasi-experimental design. The pretest was conducted 10 minutes before the first class at the beginning of the semester on March 17, 2025, and the posttest was conducted 10 minutes before the end of the final class at the end of the semester on June 20, 2025. Both assessments were organized uniformly by the course instructors during class, and participants completed the relevant scales through electronic questionnaires. The pretest was mainly used to obtain participants' baseline levels of grit and exercise addiction before the course began, whereas the posttest was used to assess corresponding changes after one semester of coursework. Both assessments were conducted during regular teaching time to minimize additional contextual interference.

2.4 Measures

2.4.1 Original Grit Scale

Grit was measured using the Original Grit Scale (Grit-O) developed by Duckworth et al. The scale contains 12 items and uses a 5-point Likert scoring format. It includes two dimensions: persistence effort and interest consistency. The former mainly reflects an individual's capacity to sustain effort when facing difficulties, setbacks, or repeated challenges, whereas the latter mainly reflects the stability of an individual's interests toward long-term goals (Duckworth et al., 2007) . Compared with the short-form scale, the Grit-O retains more complete dimensional information and can more fully reflect the overall structure of grit among college students. Previous studies have shown that

the Grit-O can be used to measure grit in college student populations and has good applicability(Duckworth et al., 2007; Li et al., 2025c).

2.4.2 Exercise Addiction Inventory

Exercise addiction was measured using the Exercise Addiction Inventory (EAI). The scale was developed by Griffiths et al. and consists of six items rated on a 5-point Likert scale. It mainly covers core components such as salience, mood modification, tolerance, withdrawal, conflict, and relapse, thereby providing a concise assessment of imbalanced involvement in exercise participation (Griffiths et al., 2005b) . Because the EAI is brief, convenient to administer, and efficient for screening, it has been widely used to identify the risk of exercise addiction in general exercising populations and youth samples(Lichtenstein et al., 2018) . The total EAI score was used as an indicator of exercise addiction level, with higher scores indicating a stronger tendency toward exercise addiction.

2.5 Statistical analysis

All data were analyzed using SPSS 27.0, with the significance level set at 0.05, two-tailed. First, descriptive statistics were calculated for the pretest, posttest, and change scores of each indicator. The Kolmogorov–Smirnov test was used to examine the distributional characteristics of the data, and Levene's test was used to assess homogeneity of variance (Razali and Wah, 2011). Given the unequal sample sizes between the two groups, Mann–Whitney U tests were used for between-group comparisons of pretest scores, posttest scores, and change scores between the open natural setting group and the strictly site-constrained group. In addition, sex differences in the change scores of each indicator were further compared within each site type. The effect size for the Mann–Whitney U test was expressed as r and calculated as $r=|Z|/\sqrt{N}$(Fritz et al., 2012) . In the main analysis, a 2 × 2 repeated-measures analysis of variance was conducted, with site type as the between-subjects factor and time as the within-subjects factor. The main effects and interaction effects were examined separately for the grit total score, persistence effort, interest consistency, and EAI score, and partial η^2 was reported as the effect size(Bakeman, 2005).For indicators with significant interaction effects, simple-effects analyses were further conducted. Finally, change scores for each variable were calculated by subtracting the pretest score from the posttest score. Pearson correlation analyses were then performed in the total sample and within each group to examine the relationships among changes in the grit total score, persistence effort, interest consistency, and EAI score.

3. Results

3.1 Descriptive analysis

As shown in Table 2, the open natural setting group (N = 213) generally showed a more favorable direction of change. The EAI score decreased from 17.80 ± 3.173 at pretest to 15.44 ± 3.914 at posttest, with a change score of −2.36 ± 5.145, indicating an overall reduction in exercise addiction. Meanwhile, the grit total score increased from 37.80 ± 5.701 to 39.53 ± 5.260, with a change score of 1.73 ± 7.884, and persistence effort increased from 19.11 ± 4.457 to 20.46 ± 3.306, with a change score of 1.36 ± 5.774. These results suggest upward trends in both grit and its effort-related dimension.

In contrast, in the strictly site-constrained group (N = 605), the EAI score increased from 17.16 ± 3.467 to 17.35 ± 3.265, with a change score of 0.20 ± 3.962, showing no decreasing trend. The grit total score decreased from 37.89 ± 5.401 to 37.71 ± 5.460, with a change score of −0.18 ± 6.148, and persistence effort decreased from 19.27 ± 3.934 to 19.12 ± 4.032, with a change score of −0.15 ± 4.628. Overall, the magnitude of change in this group was small and did not indicate any clear improvement.

3.2 Effects of site type on changes in grit

As shown in Table 3, there were no significant baseline differences between the open natural setting group (N = 213) and the strictly site-constrained group (N = 605) in the grit total score or persistence effort, with $p = 0.497$ and $p = 0.670$, respectively. This indicates that the two groups were comparable at baseline. However, significant between-group differences were observed in both indicators at posttest and in their change scores, all at $p < 0.001$. By contrast, interest consistency differed significantly only at posttest ($p = 0.010$), whereas the between-group difference in its change score was not significant ($p = 0.080$). The time × site type interaction effect was significant for the grit total score, $F(1,816) = 13.06$, $p < 0.001$, partial $\eta^2 = 0.016$. A significant interaction effect was also observed for persistence effort, $F(1,816) = 14.63$, $p < 0.001$, partial $\eta^2 = 0.018$, whereas no significant interaction was found for interest consistency (Table 4). Simple-effects analyses (Table 5) further showed that the open natural setting group had significant increases in the grit total score ($\Delta = 1.732$, $p = 0.002$) and persistence effort ($\Delta = 1.357$, $p < 0.001$), whereas no significant pre–post changes were observed in the strictly site-constrained group. Overall, the differential effect of site type was mainly reflected in the grit total score and the persistence effort dimension, but not clearly in interest consistency.

3.3 Effects of site type on changes in exercise addiction

After the course, the EAI score in the open natural setting group was significantly lower than that in the strictly site-constrained group, and the between-group difference in change scores was also significant, both at $p < 0.001$. These findings suggest that the two site types were associated with distinct patterns of change in exercise addiction (Table 3). Table 4 further shows that the main effect of time on EAI score was significant, $F(1,816) = 9.69$, $p = 0.002$, partial $\eta^2 = 0.012$. The main effect of site type was also significant, $F(1,816) = 8.96$, $p = 0.003$, partial $\eta^2 = 0.011$. In addition, the time × site type interaction effect was significant and showed the largest effect size among all indicators, $F(1,816) = 55.53$, $p < 0.001$, partial $\eta^2 = 0.064$. Simple-effects analyses (Table 5) indicated that the EAI score decreased significantly in the open natural setting group ($\Delta = -2.357$, $p < 0.001$), whereas no significant pre–post change was found in the strictly site-constrained group ($\Delta = 0.197$, $p = 0.223$). Overall, courses delivered in open natural settings showed a more favorable trend in reducing exercise addiction.

3.4 Relationship between changes in grit and changes in exercise addiction

Pearson correlation analyses showed that, in the total sample, changes in exercise addiction were significantly and negatively correlated with changes in the grit total score ($r = -0.096$, $p < 0.01$) and more strongly negatively correlated with changes in persistence effort ($r = -0.180$, $p < 0.01$), whereas the correlation with changes in interest consistency was not significant ($r = 0.059$, $p > 0.05$) (Table 6). These findings indicate

that increases in grit, particularly in the effort-related dimension, were more likely to be accompanied by decreases in exercise addiction.

Subgroup analyses further revealed clear site-related differences in this association pattern. In the open natural setting group, changes in exercise addiction were significantly and negatively correlated with changes in the grit total score ($r = -0.240$, $p < 0.01$) and persistence effort ($r = -0.276$, $p < 0.01$), whereas no significant association was observed with changes in interest consistency ($r = -0.066$, $p > 0.05$) (Table 7). In the strictly site-constrained group, changes in exercise addiction were not significantly correlated with changes in the grit total score ($r = 0.03$, $p > 0.05$), were only weakly negatively correlated with changes in persistence effort ($r = -0.08$, $p < 0.05$), and were significantly positively correlated with changes in interest consistency ($r = 0.14$, $p < 0.01$) (Table 8). Overall, open natural settings appeared more likely to foster an association pattern characterized by "increased grit–reduced exercise addiction."

3.5 Sex differences across site types

Sex differences within each site type were also examined. In the open natural setting group, only changes in interest consistency showed a significant sex difference, with females exhibiting greater increases than males ($p = 0.037$). No significant sex differences were found in changes in the grit total score, persistence effort, or EAI score. In the strictly site-constrained group, no significant sex differences were observed in changes in the grit total score, persistence effort, interest consistency, or EAI score (Table 9).

4. Discussion

The most important finding of this study is that, compared with strictly site-constrained courses, courses delivered in open natural settings may be more likely to produce a combined pattern of "increased grit total score—increased persistence effort—reduced exercise addiction." This finding is consistent with evidence that the combination of nature exposure and physical activity may generate additional psychological benefits (Barton and Pretty, 2010; Nguyen et al., 2023b; Singh et al., 2023; Tyne et al., 2024). In terms of effect sizes, the between-group difference in the change score of the grit total score was small ($r = 0.146$), and the between-group difference in the change score of persistence effort was also small ($r = 0.123$), whereas the effect size for the change in EAI score was relatively larger ($r = 0.232$). This suggests that site type may differentiate changes in exercise addiction more clearly than changes in grit. Open natural settings may not simply make courses more enjoyable; rather, they may more fundamentally reshape the way students organize their engagement into persistence, adaptation, or risk-related responses. Recent empirical research has shown that mountaineering courses themselves can improve grit levels among college students (Li et al., 2025b), and direct comparisons between traditional physical education courses and outdoor education courses have also indicated that outdoor education has greater advantages in cultivating grit among college students, particularly in the dimension of persistence effort. These findings are highly consistent with the results of the present study (Li et al., 2025c)。

With respect to grit, the open natural setting group showed significant increases in the grit total score and persistence effort, whereas the strictly site-constrained group showed no significant pre–post changes. This indicates that the effect of site type was mainly reflected in the effort-related dimension rather than in the interest consistency dimension. We believe that this may be related to environmental variation, route judgment, task cooperation, and responses to uncertain situations in open natural setting courses. In such courses, students need to sustain engagement and adjust their action strategies in environments that are not fully controllable, which may more readily activate persistence effort (Hagger and Hamilton, 2019; Jiang et al., 2019; Wang et al., 2021). The absence of a significant time × site type interaction for interest consistency suggests that one semester of course exposure may be more likely to change students' behavioral persistence than their long-term consistency of interest. This interpretation is broadly consistent with findings in higher education concerning the relationships among self-efficacy, effort regulation, and learning engagement (Van Dinther et al., 2011; Honicke and Broadbent, 2016)。

From the perspective of exercise addiction, the key finding in the open natural setting group was not merely that its score was "lower," but that the decrease in EAI score occurred alongside increases in grit and persistence effort. We believe that courses delivered in open natural settings may reduce the pressure associated with single-outcome performance evaluation and fixed performance standards, making exercise engagement more exploratory, experiential, and regulatory, rather than a form of compulsive involvement organized around winning, achievement, or repetitive training. This explanation is consistent with a basic premise in exercise addiction research: high participation does not necessarily equate to high addiction risk; the key issue is whether exercise behavior shows symptomatic features such as loss of control, conflict, withdrawal, persistent exercise, and functional impairment(Hamer and Karageorghis, 2007; Colledge et al., 2020; Trott et al., 2020b). By contrast, strictly site-constrained courses may be more likely to narrow course experiences into fixed procedures, repeated practice, and explicit standards of completion. When such engagement is combined with perfectionistic tendencies or external evaluative pressure, interest may be pushed toward a more rigid form of involvement rather than healthier long-term participation (Curran et al., 2015; Çakın et al., 2021). This may also help explain why changes in interest consistency were positively correlated with changes in EAI score in the strictly site-constrained group. In a more controlled practice environment, "liking this activity more and more" does not necessarily indicate a healthier pattern; it may also reflect stronger identity attachment and a growing sense that the activity cannot be interrupted (Curran et al., 2015; Kovacsik et al., 2019; Trott et al., 2020a). This interpretation is consistent with research on the relationship between passion and exercise addiction, as well as studies on obsessive passion (Sicilia et al., 2020).

The analysis of sex differences showed that, in the open natural setting group, females had significantly greater changes in interest consistency than males, although the effect size was small ($r = 0.143$). Moreover, this difference did not extend to the grit total score, persistence effort, or EAI score. We believe that this may be related to the

fact that open natural setting courses provide more opportunities for cooperative experience, environmental exploration, and non-singular competitive evaluation. Such courses may be more likely to promote increases in course-related interest consistency among some female students (Easterlin et al., 2019; Wang et al., 2025).

The correlation analyses further indicated that the relationship between changes in grit and changes in exercise addiction was not linear or uniform, but varied according to site type. In open natural settings, changes in EAI score were negatively correlated with changes in the grit total score and persistence effort, suggesting that persistence effort developed in this context may be closer to a form of adaptive persistence. In strictly site-constrained settings, however, this relationship was markedly weakened and even became more complex, indicating that the association between grit and exercise addiction may be influenced by site type (Hagger and Hamilton, 2019; Pálfi et al., 2021).

Overall, site type may not be a neutral background condition in university physical education courses, but rather an important contextual factor that shapes the direction of changes in grit and exercise addiction among college students. Compared with strictly site-constrained courses, courses delivered in open natural settings were more likely to be accompanied by increases in the grit total score and persistence effort, as well as a more favorable decline in EAI score. The relationship between changes in grit and changes in exercise addiction also differed clearly by site type. This suggests that the educational significance of grit is not fixed, but may be shaped by site-related factors. Therefore, when evaluating the educational value of university physical education courses, researchers should examine not only whether such courses promote the development of positive qualities, but also whether they are accompanied by changes in addiction-related risk.

5. Conclusion

This study showed that, in courses delivered in open natural settings, college students exhibited greater increases in the grit total score and the persistence effort dimension than those in strictly site-constrained courses. At the same time, exercise addiction showed a more favorable decreasing trend. Clear site-related differences were observed in the relationship between changes in grit and changes in exercise addiction. In open natural settings, increases in persistence effort were more likely to be accompanied by decreases in exercise addiction, whereas in strictly site-constrained settings, this relationship was relatively weaker and showed a more complex pattern. Regarding sex differences, females in the open natural setting group showed significantly greater changes in interest consistency than males. Overall, the direction of changes in grit and exercise addiction, as well as the way these changes were associated with each other, differed across course site types.

6. Limitations

This study adopted a pretest–posttest quasi-experimental design rather than a randomized assignment design. In addition, the findings reflect short-term changes observed at the end of the course and cannot determine whether the effects of different site types are stable over the long term. Future studies should adopt more rigorous research designs, incorporate longitudinal follow-up, and include more objective

indicators to further examine the sustainability of changes in grit and exercise addiction across different course ecologies.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of China University of Geosciences (Wuhan). Written informed consent was obtained from all participants prior to participation. Written informed consent was obtained from all participants prior to participation.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Table 1. Participant characteristics

Group	Total, n	Female, n	Height (cm)	Weight (kg)
Open natural setting group	213	69	171.9±8.44	65.25±12.8
Strictly site-constrained group	605	186	170.48±10.91	64.45±13.58

Table 2. Descriptive statistics and distribution characteristics of pretest, posttest, and change scores for each indicator in the open natural setting and strictly

site-constrained groups

Table 2. Descriptive statistics and distribution characteristics of pretest, posttest, and change scores for each indicator in the open natural setting and strictly site-constrained groups

Scales	Variable	Mean ± SD		Skewness		Kolmogorov-Smirnov test			
						D		p	
		Open natural setting group	Strictly site-constrained group	Open natural setting group	Strictly site-constrained group	Open natural setting group	Strictly site-constrained group	Open natural setting group	Strictly site-constrained group
EAI Score	pre	17.80±3.173	17.16±3.467	-0.296	0.390	0.117	0.113	0.000***	0.000***
	post	15.44±3.914	17.35±3.265	0.134	0.433	0.120	0.132	0.000***	0.000***
	Post-Pre	-2.36±5.145	0.20±3.962	0.073	-0.173	0.076	0.085	0.005**	0.000***
Grit total score	pre	37.80±5.701	37.89±5.401	0.385	0.348	0.114	0.115	0.000***	0.000***
	post	39.53±5.260	37.71±5.460	0.103	0.685	0.096	0.156	0.000***	0.000***
	Post-Pre	1.73±7.884	-0.18±6.148	-0.199	0.127	0.075	0.085	0.005**	0.000***
Persistence effort	pre	19.11±4.457	19.27±3.934	-0.238	-0.033	0.082	0.117	0.001**	0.000***
	post	20.46±3.306	19.12±4.032	0.302	-0.024	0.119	0.141	0.000***	0.000***
	Post-Pre	1.36±5.774	-0.15±4.628	0.255	0.003	0.060	0.093	0.057	0.000***
Interest consistency	pre	18.69±3.373	18.61±3.273	0.044	-0.111	0.130	0.149	0.000***	0.000***
	post	19.07±3.171	18.59±3.424	-0.504	0.269	0.131	0.139	0.000***	0.000***
	Post-Pre	0.38±4.553	-0.03±4.230	-0.292	0.061	0.096	0.091	0.000***	0.000***

Table 3. Between-group differences in each indicator between the open natural setting and strictly site-constrained groups

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Measure	Time point	Open natural setting group(n=213)	Strictly site-constrained group(n=605)	Z value	p	r
EAI Score	Pre	18.0(16.0,20.0)	17.0(15.0,19.0)	-3.086	0.002**	0.108
	Post	16.0(12.0,18.0)	18.0(16.0,19.0)	-5.884	<0.001**	0.206
	Post-Pre	-2.0(-6.0,1.500)	0.0(-2.0,2.0)	-6.631	<0.001**	0.232
Grit total score	Pre	37.0(34.0,42.0)	37.0(35.0,40.0)	-0.68	0.497	0.024
	Post	40.0(36.0,43.0)	36.0(35.0,40.0)	-5.247	<0.001**	0.183
	Post-Pre	2.0(-2.500,7.0)	0.0(-3.0,3.0)	-4.166	<0.001**	0.146
Persistence Effort Score	Pre	19.0(17.0,22.0)	19.0(17.0,21.500)	-0.426	0.67	0.015
	Post	20.0(18.0,23.0)	18.0(17.500,22.0)	-4.488	<0.001**	0.157
	Post-Pre	2.0(-3.0,5.0)	0.0(-3.0,2.0)	-3.526	<0.001**	0.123
Interest consistency Score	Pre	18.0(17.0,21.0)	18.0(17.0,21.0)	-0.152	0.879	0.005
	Post	19.0(18.0,21.0)	18.0(17.0,21.0)	-2.568	0.010*	0.090
	Post-Pre	0.0(-3.0,4.0)	0.0(-3.0,2.0)	-1.752	0.08	0.061

* p<0.05 ** p<0.01

Table 4. Results of the 2 x 2 repeated-measures ANOVA examining the effects of site type and time on each outcome

Table 4. Results of the 2 × 2 repeated-measures ANOVA examining the effects of site type and time on each outcome

Outcome	Effect	F	df	p	Partial η^2
Grit total score	Main effect of time	1.87	1, 816	0.172	0.002
Grit total score	Main effect of site type	6.38	1, 816	0.012	0.008
Grit total score	Time × site type interaction	13.06	1, 816	<0.001	0.016
Persistence effort	Main effect of time	1.94	1, 816	0.165	0.002
Persistence effort	Main effect of site type	5.73	1, 816	0.017	0.007
Persistence effort	Time × site type interaction	14.63	1, 816	<0.001	0.018
Interest consistency	Main effect of time	0.26	1, 816	0.610	0.000
Interest consistency	Main effect of site type	1.88	1, 816	0.171	0.002
Interest consistency	Time × site type interaction	1.38	1, 816	0.241	0.002
EAI Score	Main effect of time	9.69	1, 816	0.002	0.012
EAI Score	Main effect of site type	8.96	1, 816	0.003	0.011
EAI Score	Time × site type interaction	55.53	1, 816	<0.001	0.064

Table 5. Simple-effects analyses and between-group differences in change scores (change score = post − pre)

Table 5. Simple-effects analyses and between-group differences in change scores (change score = post − pre)

Outcome	Comparison	Change score / Difference	F (df)	p	Partial η^2
Grit total score	Open natural setting group: post− pre	1.732	10.29 (1, 212)	0.002	0.046
Grit total score	Strictly site-constrained group: post − pre	-0.180	0.52 (1, 604)	0.471	0.001
Grit total score	Difference in change scores: open natural setting group − strictly site-constrained group	1.913	13.06 (1, 816)	<0.001	0.016
Persistence effort	Open natural setting group: post− pre	1.357	11.76 (1, 212)	<0.001	0.053
Persistence effort	Strictly site-constrained group: post − pre	-0.152	0.65 (1, 604)	0.419	0.001
Persistence effort	Difference in change scores: open natural setting group − strictly site-constrained group	1.509	14.63 (1, 816)	<0.001	0.018
Interest consistency	The time × site type interaction was not significant; therefore, no simple-effects analysis was conducted				
EAI Score	Open natural setting group: post− pre	-2.357	44.69 (1, 212)	<0.001	0.174
EAI Score	Strictly site-constrained group: post − pre	0.197	1.49 (1, 604)	0.223	0.002
EAI Score	Difference in change scores: open natural setting group − strictly site-constrained group	-2.554	55.53 (1, 816)	<0.001	0.064

Table 6. Pearson correlation analysis in the total sample

Table 6. Pearson correlation analysis in the total sample

Variable	Mean	SD	EAI Score Post-Pre	Grit total score Post-Pre	Persistence effort Post-Pre	Interest consistency Post-Pre
EAI Score Post-Pre	-0.468	4.442	1			
Grit total scorePost-Pre	0.318	6.691	-0.096**	1		
Persistence effort Post-Pre	0.241	4.993	-0.180**	0.764**	1	
Interest consistency Post-Pre	0.077	4.317	0.059	0.666**	0.028	1

* p<0.05 ** p<0.01

Table 7. Pearson correlation analysis in the open natural setting group

Table 7. Pearson correlation analysis in the open natural setting group

Variable	Mean	SD	EAI Score Post-Pre	Grit total score Post-Pre	Persistence effort Post-Pre	Interest consistency Post-Pre
EAI Score Post-Pre	-2.357	5.145	1			
Grit total score Post-Pre	1.732	7.884	-0.240**	1		
Persistence effort Post-Pre	1.357	5.774	-0.276**	0.821**	1	
Interest consistency Post-Pre	0.376	4.553	-0.066	0.690**	0.154*	1

* p<0.05 ** p<0.01

Table 8. Pearson correlation analysis in the strictly site-constrain

Table 8. Pearson correlation analysis in the strictly site-constrained group

Variable	Mean	SD	EAI Score Post-Pre	Grit total score Post-Pre	Persistence effort Post-Pre	Interest consistency Post-Pre
EAI Score Post-Pre	0.2	3.96	1			
Grit total score Post-Pre	-0.18	6.15	0.03	1		
Persistence effort Post-Pre	-0.15	4.63	-0.08*	0.73**	1	
Interest consistency Post-Pre	-0.03	4.23	0.14**	0.66**	-0.04	1

* p<0.05 ** p<0.01

Table 9. Sex differences in change scores within each site type (change score = post - pre)

Table 9. Sex differences in change scores within each site type (change score = post − pre)

Site type	Variable	Male, n	Male change score, median (P25, P75)	Female, n	Female change score, median (P25, P75)	U	Z	p	r
Open natural setting group	Grit total score	144	1.50 (-3.00, 7.00)	69	3.00 (-1.00, 8.00)	4383.00	-1.39	0.165	0.095
Open natural setting group	Persistence effort	144	1.50 (-3.00, 5.00)	69	2.00 (-3.00, 5.00)	4677.00	-0.69	0.489	0.047
Open natural setting group	Interest consistency	144	0.00 (-3.25, 3.00)	69	1.00 (-1.00, 5.00)	4090.50	-2.09	0.037	0.143
Open natural setting group	EAI Score	144	-2.00 (-6.00, 1.00)	69	-3.00 (-7.00, 3.00)	4956.00	-0.03	0.978	0.002
Strictly site-constrained group	Grit total score	419	0.00 (-3.00, 3.00)	186	0.00 (-3.00, 3.00)	37574.00	-0.60	0.549	0.024
Strictly site-constrained group	Persistence effort	419	0.00 (-3.00, 2.00)	186	0.00 (-3.00, 2.00)	38281.00	-0.24	0.809	0.010
Strictly site-constrained group	Interest consistency	419	0.00 (-3.00, 2.00)	186	0.00 (-3.00, 3.00)	37781.00	-0.50	0.620	0.020
Strictly site-constrained group	EAI Score	419	0.00 (-2.00, 3.00)	186	0.00 (-2.00, 2.00)	39316.00	0.28	0.777	0.011

Supplementary Files

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