

Effects of open- and closed-skill sports on physical fitness, emotional well-being, and perceived stress among university students: A quasi-experimental study

LI LUYAN¹; WAN AHMAD MUNSIF WAN PA^{2*}; NURWINA AKMAL BINTI ANUAR³

^{1,2,3}Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, 43600, Selangor, MALAYSIA

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Abstract

To examine the effects of open-skill and closed-skill sports on physical fitness, emotional well-being, and perceived stress among university students, and to compare the intervention effects of these two exercise types. A quasi-experimental design was adopted. The study was conducted at a private university in Henan Province, China, and the participants were sophomore students. The participants were assigned to a control group (CG), a closed-skill sports intervention group (IG1), and an open-skill sports intervention group (IG2). Physical fitness, emotional well-being, and perceived stress were assessed before and after the intervention. Physical fitness was evaluated according to the National Student Physical Health Standard (NSPHS). Emotional well-being was measured using the Positive and Negative Affect Schedule (PANAS), and perceived stress was assessed using the Perceived Stress Scale (PSS-10). Data were analyzed using descriptive statistics, one-way analysis of variance, the chi-square test, and repeated-measures analysis of variance. Before the intervention, no significant differences were found among the three groups in sex, age, height, weight, BMI, or any of the outcome variables (all $p > 0.05$), indicating good baseline comparability. After the intervention, physical fitness improved significantly in both IG1 and IG2, and both groups performed better than the CG, although no significant difference was found between the two intervention groups. In terms of emotional well-being, both IG1 and IG2 showed significant increases in positive affect and significant decreases in negative affect, with IG2 demonstrating significantly greater improvements than IG1. For perceived stress, both IG1 and IG2 showed significant reductions, but the effect was most pronounced in IG2, whose post-intervention perceived stress level was significantly lower than that of both IG1 and the CG. Both open-skill and closed-skill sports were effective in improving physical fitness and had positive effects on emotional well-being and perceived stress among university students. Compared with closed-skill sports, open-skill sports showed more pronounced advantages in promoting emotional well-being and reducing perceived stress.

Keywords: open-skill sports; closed-skill sports; university students; physical fitness; emotional well-being; perceived stress

Introduction

Regular physical activity provides significant physical and mental health benefits (WHO, 2024). Ensuring college students get physical activity is crucial for maintaining a healthy lifestyle (Al Salim, 2024). Undergraduate students are a special group who are in the process of transitioning from adolescence to adulthood and experiencing all sorts of changes (Chu, Liu, Takayanagi, Matsushita, & Kishimoto, 2023). Existing research indicates that physical activity is closely related to physical fitness, perceived stress, and emotional health among college students (Martín-Rodríguez & González-Prieto, 2025).

Based on the differences in the environment in which motor skills are performed, sports can generally be divided into open-skill sports and closed-skill sports (F. Heilmann, H. Weinberg, & R. Wollny, 2022). Open-skill sports take place in dynamic and unpredictable environments, where athletes must constantly adjust their actions in response to external stimuli (Grosprêtre, Chotel, & Ruffino, 2025). Closed skills occur in a stable, predictable environment, and the performer knows what to do and when (Q. Gu, Zou, Loprinzi, Quan, & Huang, 2019). Existing research indicates that both types of activities can improve physical function but may also promote psychological adaptability and emotional regulation (Feng, Zhang, Jin, & Shi, 2023).

Table tennis, are widely considered to be typical open-skill sports (Florian Heilmann, Henrietta Weinberg, & Rainer Wollny, 2022). Table tennis is characterized by its fast pace, high interactivity, and high cognitive-motor integration requirements (Guarnieri, Laurenti, Mazzei, Presta, & Condello, 2025). Table tennis integrates motor, cognitive, and psychosocial skills, requiring quick decision-making, precise coordination, and interpersonal communication abilities (J. Liu, 2025). In contrast, aerobic running is typically classified as a closed-skill activity performed in a stable and predictable environment, characterized by repetitive and automated movement patterns (Q. Gu et al., 2019).

Emotional well-being, and perceived stress are important indicators of mental health, especially among university students (Haruna, Mohammed, & Braimah, 2025). Emotional well-being reflects an individual's capacity to experience positive affect while maintaining a stable and balanced emotional state (Park et al., 2023). In contrast, perceived stress refers to individuals' subjective appraisal of stressors in their environment and their perceived ability to cope with these demands (S. Liu, Lithopoulos, Zhang, Garcia-Barrera, & Rhodes, 2021). Previous research has shown that engagement in physical activity can mitigate stress responses and contribute to improvements in emotional well-being (Mahindru, Patil, & Agrawal, 2023). Nevertheless, the mechanisms through which different forms of physical activity influence psychological outcomes remain insufficiently understood. In particular, empirical evidence regarding the role of open-skill sports in promoting emotional well-being and regulating perceived stress among university students is still relatively limited.

Physical fitness has been widely recognized as a key factor linking participation in physical activity with psychological health outcomes (Granero-Jiménez, López-Rodríguez, Dobarrio-Sanz, & Cortés-Rodríguez, 2022). Improvements in physical fitness can enhance individuals' physiological adaptability and resilience to stress, thereby facilitating better emotional regulation and overall psychological well-being (Han et al., 2025). However, much of the existing research has primarily focused on general physical activity or aerobic exercise interventions (Kettle et al., 2022). Relatively few studies have examined the integrated effects of open-skill sport training on physical fitness, emotional well-being, and perceived stress within a unified analytical framework.

Against this background, the present study employs table tennis training and aerobic running as empirical context to investigate the influence of open-skill sport and closed-skill sport participation on multidimensional health outcomes among university students. This study examines how participation in open-skill sport and closed-skill sport relates to changes in physical fitness, emotional well-being, and perceived stress. By integrating both physical and psychological health indicators, this research seeks to advance understanding of the health-promoting potential of different kinds of sports and to provide empirical evidence to inform the development of sport-based health promotion strategies in higher education settings.

Methods

Research and Experimental Design

This quasi-experimental study was conducted in Henan Province, China. Participants were initially randomly assigned to a control group, an intervention group 1, or an intervention group 2. The control group did not participate in any additional physical activity intervention during the study period and only maintained their usual daily study and lifestyle routines. Intervention group 1 (IG1) participated in closed-skill exercise training, with aerobic running as the primary form of activity. Intervention group 2 (IG2) participated in open-skill exercise training, for which table tennis was adopted in this study. To minimize participant attrition, participants were allowed to be reassigned to other groups if necessary. These arrangements were specified before the experimental procedure began. However, no participants were reassigned during the intervention period.

Participants

An a priori statistical power analysis was conducted using G*Power 3.1.9.7. Using a repeated-measures ANOVA design (3 groups $\times$ 2 measurement time points), with a significance level of $\alpha = 0.05$, statistical power of 0.80, and a medium effect size ($f = 0.25$), the minimum required sample size was estimated to be 42 participants. To reduce potential bias caused by sample attrition, an additional 20% was added to the estimated sample size to ensure that the final sample size would meet the study requirements. Therefore, the required sample size for this study was determined to be 51 participants.

Participants were recruited directly by the researchers. Recruitment information was disseminated through the WeChat platform of a university in Henan Province and through classroom announcements made by teachers. A total of 66 students responded to the recruitment notice. After screening, 6 students who had previously received formal table tennis training were excluded. Ultimately, 60 participants met the inclusion criteria for this study, with 20 participants in each group.

The inclusion and exclusion criteria are shown in Table 1.

Table 1. Inclusion and Exclusion Criteria

Item	Criteria
Inclusion criteria	Physically healthy, with no history of disease or injury affecting normal exercise participation Aged between 19 and 23 years No prior formal table tennis training
Exclusion criteria	Presence of language communication or cultural barriers Severe fear of or maladjustment to physical activity

Intervention Procedure

The intervention lasted for 12 weeks, with two sessions per week and 90 minutes per session. IG1 participated in closed-skill exercise training, with aerobic running as the primary form of activity. IG2 participated in the open-skill table tennis training program designed for this study. The CG did not participate in any additional physical activity intervention and only maintained their usual daily study and lifestyle routines. Before the intervention began, informed consent forms, demographic data, and baseline data on physical fitness, emotional well-being, and perceived stress were collected from all participants.

During the intervention period, Intervention Group 1 (IG1) and Intervention Group 2 (IG2) were maintained at the same exercise intensity. The average exercise intensity throughout the 12-week intervention was controlled at 70%-80% of maximum heart rate. Each intervention session lasted 90 minutes, including 15 minutes of warm-up, 60 minutes of main training, and 15 minutes of stretching and cool-down activities. The table tennis training content for IG2 included serving, serve return, forehand and backhand attacks, pushing and spin shots, defensive skills, footwork and rapid reaction training, full-table control and tactical awareness training, multiball training, and match simulation. Fig.1 presents the design of the overall intervention procedure.

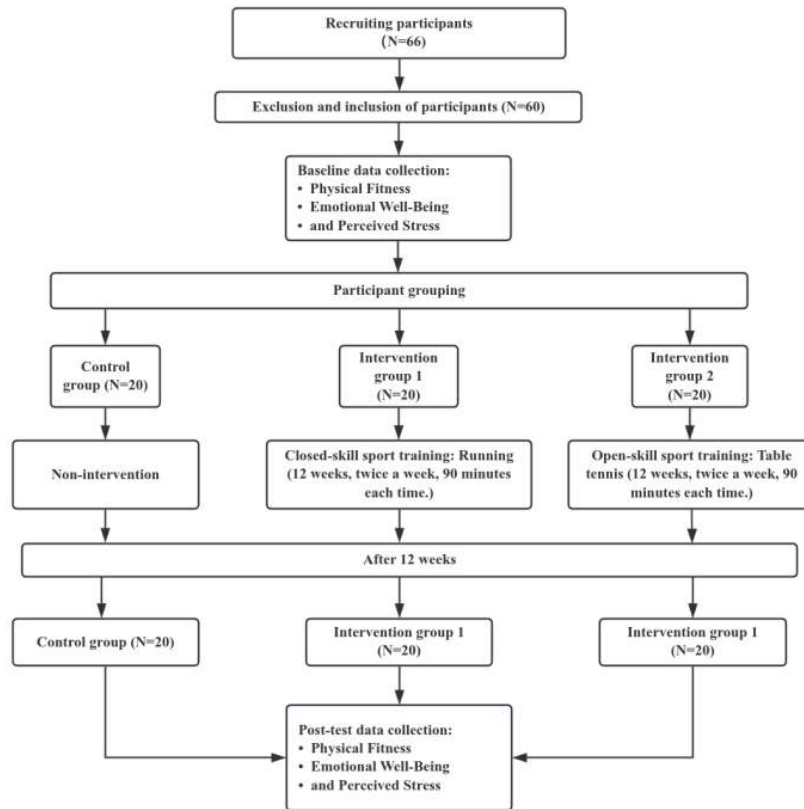


Fig.1. Flow diagram of participant recruitment, grouping, and intervention procedures

Measurement

Physical fitness

The physical fitness test in this study was conducted in accordance with the National Student Physical Health Standard (NSPHS). The NSPHS was uniformly developed by relevant national authorities and is applicable to the evaluation of Chinese students' physical health. It has been widely adopted in physical health monitoring and related research in China and has demonstrated good scientific rigor and applicability (Chen, Cui, Zhang, & Peng, 2020).

In addition, the physical fitness test items included body mass index (BMI), vital capacity, standing long jump, sit-and-reach, pull-ups (for males) / one-minute sit-ups (for females), 50-m sprint, and 1000-m run (for males) / 800-m run (for females). All test scores were calculated strictly in accordance with the standard, and each indicator was assigned a score based on the prescribed weighting. The total score was 100 points and was calculated as follows: Total score = BMI score $\times$ 0.15 + vital capacity score $\times$ 0.15 + 50-m sprint score $\times$ 0.20 + sit-and-reach score $\times$ 0.10 + standing long jump score $\times$ 0.10 + sit-ups/pull-ups score $\times$ 0.10 + 800-m/1000-m run score $\times$ 0.20. In this study, the intervention effect on physical fitness was presented using the total score. All participants were required to complete a warm-up before the physical fitness test. The physical fitness test was administered by assessors recruited by the research team.

Emotional Well-Being

Emotional well-being was assessed using the Positive and Negative Affect Schedule (PANAS) (Watson, Clark, & Tellegen, 1988). The scale consists of 20 items, including 10 positive affect items (e.g., excited, active, and interested) and 10 negative affect items (e.g., angry, upset, and nervous). Participants were asked to rate each item based on their emotional experiences over the past week using a 5-point Likert scale ranging from 1 (very slightly or not at all) to 5 (extremely).

In this study, the scores for positive affect and negative affect were calculated and presented using the mean score on a 5-point scale. A higher score for positive affect indicates a higher level of positive emotional experience, whereas a higher score for negative affect indicates a higher level of negative emotional experience.

The PANAS has been widely used in research on emotional well-being and psychology and has also been extensively applied in studies conducted by Chinese scholars, showing good reliability and validity across multiple studies (Y. Wang, Jing, Han, Jing, & Xu, 2020).

Perceived Stress

Perceived stress was measured using the Perceived Stress Scale (PSS-10) (Cohen, 1988). The scale consists of 10 items and assesses participants' perceptions of stressors in daily life over the past month. Participants rated each item based on their experiences during the previous month using a 5-point Likert scale ranging from 0 (never) to 4 (very often).

In this study, perceived stress was calculated and reported using the mean score, with higher scores indicating higher levels of perceived stress. The PSS-10 has been widely used in studies conducted by Chinese scholars and has shown good reliability and validity (Lu et al., 2017).

Data Analysis

Data analysis was performed using SPSS 29.0. First, descriptive statistics were calculated to examine the overall characteristics of the groups. To provide a concise summary of the demographic information, means and standard deviations were computed. For comparisons of baseline differences between groups, one-way analysis of variance (ANOVA) was used for continuous variables, and the chi-square test was used for categorical variables.

To examine differences between the intervention groups and the control group, a two-way repeated-measures ANOVA was conducted to test the effects of different exercise types on physical fitness, emotional well-being, and perceived stress. Time (pre vs. post) was treated as the within-subject factor, and group (CG, IG1, and IG2) was treated as the between-subject factor. Before the analysis, the assumption of normality was evaluated using skewness and kurtosis values. All variables were approximately normally distributed. Because the within-subject factor included only two time points, the assumption of sphericity was not violated. When a significant interaction effect was observed, simple effects analysis and post hoc comparisons were conducted to further examine between-group differences. All statistical tests were performed using $p < 0.05$ as the level of significance, and effect sizes were reported as partial eta squared (η^2p).

Ethical Considerations

This study was reviewed and approved by the Ethics Committee of Xinxiang Institute of Engineering, with the ethical approval number xxgc-2025-008. All participants provided written informed consent before participating in the study. They were clearly informed of the study purpose, procedures, potential risks, and possible benefits, and their participation was entirely voluntary. Participants were also informed that they had the right to withdraw from the study at any time without any penalty or adverse consequences.

All data were kept strictly confidential and anonymized using unique participant codes to ensure that participants' privacy was protected. Personal identifying information was stored separately from the research data, and all electronic records were kept on password-protected devices to ensure data security. The entire research process was conducted in accordance with the ethical principles of the Declaration of Helsinki to safeguard the rights and safety of all participants.

Results

Baseline Comparisons

Baseline characteristics were compared across the three groups before the intervention. The results showed that there were no significant differences among the groups in demographic variables, including sex, age, height, weight, and BMI (all $p > 0.05$) (refer to Table 2). These findings indicate that the three groups were comparable at baseline and provide a basis for the subsequent analysis of intervention effects.

Table 2. Baseline comparisons of demographic, physical fitness, and psychological variables across groups (M $\pm$ SD)

Variable	CG (n=20)	IG1 (n=20)	IG2 (n=20)	F / χ^2	p
Gender (male/female)	12/8 (60.0%/40.0%)	14/6 (70.0%/30.0%)	11/9 (55.0%/45.0%)	$\chi^2 = 0.987$	0.61
Age (years)	19.25 $\pm$ 0.85	19.25 $\pm$ 1.02	19.25 $\pm$ 0.72	0	1
Height (cm)	169.00 $\pm$ 6.21	171.00 $\pm$ 7.26	167.70 $\pm$ 7.60	1.113	0.336
Weight (kg)	60.05 $\pm$ 8.32	63.70 $\pm$ 10.04	60.75 $\pm$ 6.59	1.054	0.355
BMI (kg/m ²)	20.92 $\pm$ 1.61	21.62 $\pm$ 1.61	21.56 $\pm$ 1.22	1.366	0.263

3.2 Effects of Different Types of Exercise on Physical Fitness

The results presented in Table 3 showed that group, time, and the group $\times$ time interaction all had significant effects on physical fitness (all $p < 0.001$), indicating that the pattern of change in physical fitness differed significantly across the different intervention conditions.

Table 3. Effects of group, time, and group $\times$ time on physical fitness

Source	df (Effect)	df (Error)	F	p	η^2p
Group	2	57	10.720	<0.001	0.273
Time	1	57	294.267	<0.001	0.838
Time $\times$ Group	2	57	39.875	<0.001	0.583

At the pre-test stage, no significant difference in physical fitness was found among the three groups ($p = 0.684$), indicating that the baseline levels were relatively comparable across groups. At the post-test stage, a significant difference was observed among the three groups ($p < 0.001$), suggesting that the intervention had a significant effect on physical fitness (refer to Table 4)

Table 4. Descriptive statistics and between-group comparisons of physical fitness at pre-test and post-test

Time	Mean $\pm$ SD CG (n = 20)	IG1 (n = 20)	IG2 (n = 20)	F	p
Pre-test	65.41 $\pm$ 7.02	66.73 $\pm$ 5.17	65.02 $\pm$ 7.06	0.383	0.684
Post-test	68.50 $\pm$ 5.53	79.84 $\pm$ 3.84	81.39 $\pm$ 7.23	51.280	<0.001

Further between-group simple effects analysis in Table 5 showed that, at the post-test stage, the physical fitness scores of IG1 and IG2 were both significantly higher than that of the CG ($p < 0.001$), whereas no significant difference was found between IG1 and IG2 ($p = 0.268$). The within-group simple effects analysis in Table 6 indicated that the physical fitness scores of all three groups increased significantly compared with the pre-test, with IG2 showing the largest improvement and the CG the smallest. Combined with the change trajectories before and after the intervention shown in Fig.2, these findings indicate that both exercise interventions effectively promoted improvements in physical fitness, and that both were clearly superior to the CG. Although the open-skill exercise showed a greater numerical increase, its advantage over closed-skill exercise in improving physical fitness did not reach statistical significance.

Table 5. Between-group simple effects of physical fitness at pre-test and post-test

Time	Comparison	Mean Difference	SE	t	p
Pre-test	CG vs IG1	-1.320	2.048	-0.645	0.522
Pre-test	CG vs IG2	0.390	2.048	0.190	0.850
Pre-test	IG1 vs IG2	1.710	2.048	0.835	0.407
Post-test	CG vs IG1	-11.342	1.390	-8.160	< 0.001
Post-test	CG vs IG2	-12.897	1.390	-9.279	< 0.001
Post-test	IG1 vs IG2	-1.555	1.390	-1.119	0.268

Table 6. Within-group simple effects of physical fitness over time

Group	Comparison	Mean Difference	SE	t	p
CG	Pre-test vs Post-test	-3.090	1.097	-2.817	0.007
IG1	Pre-test vs Post-test	-13.113	1.097	-11.954	< 0.001
IG2	Pre-test vs Post-test	-16.377	1.097	-14.929	< 0.001

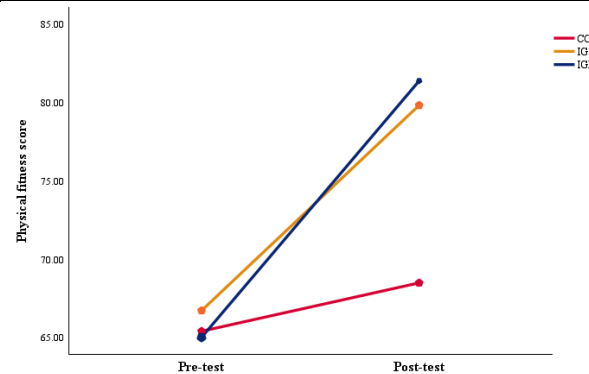


Fig.2. Changes in physical fitness scores from pre-test to post-test across groups

Effects of Different Types of Exercise on Emotional Well-Being

Regarding the effects on emotional well-being, this study included both positive affect and negative affect. Therefore, the results were statistically analyzed based on these two different emotional dimensions.

Positive Affect

The results of the repeated-measures ANOVA showed that group, time, and the group $\times$ time interaction all had significant effects on positive affect ($F = 4.914$, $p = 0.011$; $F = 81.796$, $p < 0.001$; $F = 24.892$, $p < 0.001$), indicating that the pattern of change in positive affect differed significantly across the different intervention conditions (refer to Table 7). No significant difference was found among the three groups at the pre-test stage ($p = 0.948$), indicating that the baseline levels were comparable. At the post-test stage, a significant between-group difference was observed ($F = 27.459$, $p < 0.001$) (refer to Table 8).

Table 7. Effects of group, time, and group $\times$ time on positive affect

Effect	df (Effect)	df (Error)	F	p	η^2p
Group	2	57	4.914	0.011	0.147
Time	1	57	81.796	< 0.001	0.589
Group $\times$ Time	2	57	24.892	< 0.001	0.466

Table 8. Descriptive statistics and between-group comparisons of positive affect at pre-test and post-test

Time	Mean $\pm$ SD			F	p
	CG (n = 20)	IG1 (n = 20)	IG2 (n = 20)		
Pre-test	3.265 $\pm$ 0.681	3.215 $\pm$ 0.690	3.205 $\pm$ 0.481	0.053	0.948
Post-test	3.295 $\pm$ 0.560	3.765 $\pm$ 0.387	4.305 $\pm$ 0.309	27.459	< 0.001

The between-group simple effects analysis showed that, at the post-test stage, the levels of positive affect in IG1 and IG2 were both significantly higher than that in the CG ($p = 0.019$; $p < 0.001$), and IG2 was significantly higher than IG1 ($p = 0.006$) (refer to Table 9). The within-group simple effects analysis indicated that no significant difference was found between the pre-test and post-test in the CG ($p = 0.781$), whereas both IG1 and IG2 showed significant increases compared with the pre-test (all $p < 0.001$), with IG2 showing the greatest improvement (refer to Table 10). Figure 3 further shows that the increase in positive affect was most pronounced in IG2, followed by IG1, while the CG showed only a small change.

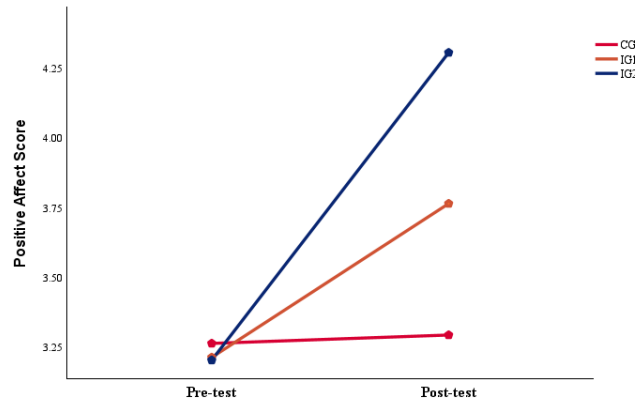
Table 9. Between-group simple effects of positive affect at pre-test and post-test

Time	Group Comparison	Mean Difference	SE	t	p
Pre-test	CG vs. IG1	0.050	0.170	0.295	0.953
Pre-test	CG vs. IG2	0.060	0.170	0.353	0.934
Pre-test	IG1 vs. IG2	0.010	0.170	0.059	0.998
Post-test	CG vs. IG1	-0.470	0.170	-2.769	0.019
Post-test	CG vs. IG2	-1.010	0.170	-5.950	< 0.001
Post-test	IG1 vs. IG2	-0.540	0.170	-3.181	0.006

Table 10. Within-group simple effects of positive affect over time

Group	Time Comparison	Mean Difference	SE	t	p
CG	Pre-test vs. Post-test	-0.030	0.107	-0.280	0.781
IG1	Pre-test vs. Post-test	-0.550	0.107	-5.128	< 0.001
IG2	Pre-test vs. Post-test	-1.100	0.107	-10.257	< 0.001

Fig.3 further illustrates that positive affect increased most markedly in IG2, followed by IG1, whereas little change was observed in the control group.


Fig.3. Changes in positive affect across groups from pre-test to post-test

Negative Affect

The results presented in Table 11 showed that negative affect was significantly influenced by group ($F = 4.256$, $p = 0.019$), time ($F = 42.917$, $p < 0.001$), and the group $\times$ time interaction ($F = 10.880$, $p < 0.001$), indicating that the pattern of change in negative affect differed significantly across the different intervention conditions.

Table 11. Effects of group, time, and group $\times$ time on negative affect

Effect	df (Effect)	df (Error)	F	p	η^2p
Group	2	57	4.256	0.019	0.130
Time	1	57	42.917	< .001	0.430
Group $\times$ Time	2	57	10.880	< .001	0.276

The results presented in Table 12 showed that no significant difference was found among the three groups at the pre-test stage ($p = 0.962$), indicating that the baseline levels were comparable across groups. At the post-test stage, a significant between-group difference was observed ($F = 25.436$, $p < 0.001$), suggesting that the intervention had a significant effect on negative affect.

Table 12. Descriptive statistics and between-group comparisons of negative affect at pre-test and post-test

Time	Mean $\pm$ SD			F	p
	CG (n = 20)	IG1 (n = 20)	IG2 (n = 20)		
Pre-test	2.600 $\pm$ 0.897	2.535 $\pm$ 0.646	2.595 $\pm$ 0.893	0.039	0.962
Post-test	2.505 $\pm$ 0.721	1.980 $\pm$ 0.244	1.470 $\pm$ 0.230	25.436	< 0.001

Further analysis showed that, at the post-test stage, negative affect in IG1 and IG2 was significantly lower than that in the CG ($p = 0.038$; $p < 0.001$), and IG2 was significantly lower than IG1 ($p = 0.045$), indicating that both exercise interventions were effective in reducing negative affect, with open-skill exercise showing a more pronounced effect (refer to Table 13).

Table 13. Between-group simple effects of negative affect at pre-test and post-test

Time	Group Comparison	Mean Difference	SE	t	p
Pre-test	CG vs. IG1	0.065	0.210	0.309	0.949
Pre-test	CG vs. IG2	0.005	0.210	0.024	1.000
Pre-test	IG1 vs. IG2	-0.060	0.210	-0.285	0.956
Post-test	CG vs. IG1	0.525	0.210	2.497	0.038
Post-test	CG vs. IG2	1.035	0.210	4.923	< 0.001
Post-test	IG1 vs. IG2	0.510	0.210	2.426	0.045

As shown in Table 14, no significant difference was found between the pre-test and post-test in the CG ($p = 0.546$), whereas both IG1 and IG2 showed significant decreases compared with the pre-test, with IG2 showing a markedly greater reduction than IG1.

Table 14. Within-group simple effects of negative affect over time

Group	Time Comparison	Mean Difference	SE	t	p
CG	Pre-test vs. Post-test	0.095	0.156	0.607	0.546
IG1	Pre-test vs. Post-test	0.555	0.156	3.548	0.001
IG2	Pre-test vs. Post-test	1.125	0.156	7.192	< 0.001

The trend shown in Fig.4 was consistent with the results above, with IG2 showing the most pronounced decrease in negative affect, while the CG showed only a small change.

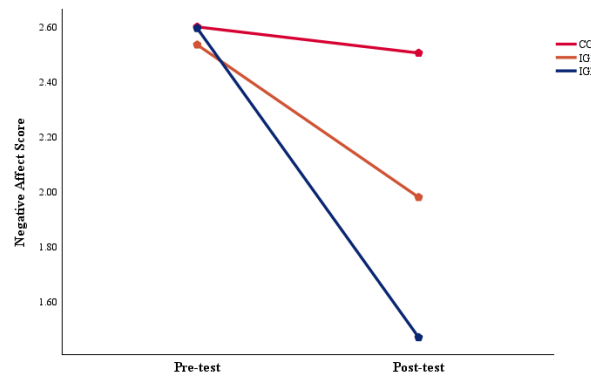


Fig.4. Changes in negative affect across groups from pre-test to post-test

Perceived Stress

Table 15 shows that the main effects of group and time, as well as the group $\times$ time interaction, were all significant for perceived stress ($p < 0.05$). Among these, the main effect of time showed the largest effect size ($\eta^2p = 0.447$), indicating that perceived stress changed markedly over time and that the pattern of change differed significantly across groups.

Table 15. Effects of group, time, and group $\times$ time on perceived stress

Effect	df (Effect)	df (Error)	F	p	η^2p
Group	2	57	4.232	.019	0.129
Time	1	57	46.091	< .001	0.447
Group $\times$ Time	2	57	8.978	< .001	0.240

As shown in Table 16, the pre-test results indicated that there were no significant differences among CG, IG1, and IG2 ($F = 0.194$, $p = 0.824$), suggesting that the three groups were comparable in terms of perceived stress at baseline. The post-test results showed a significant difference among the three groups ($F = 17.168$, $p < 0.001$), indicating that the different intervention conditions had different effects on perceived stress, and that the levels of perceived stress among participants in the three groups diverged clearly after the intervention.

Table 16. Descriptive statistics and between-group comparisons of perceived stress at pre-test and post-test

Group	Mean $\pm$ SD			F	p
	CG (n = 20)	IG1 (n = 20)	IG2 (n = 20)		
Pre-test	2.565 $\pm$ 0.781	2.655 $\pm$ 0.671	2.510 $\pm$ 0.770	0.194	0.824
Post-test	2.445 $\pm$ 0.683	2.060 $\pm$ 0.342	1.525 $\pm$ 0.402	17.168	< 0.001

The pairwise comparisons further showed that, at the post-test stage, a significant difference was found between CG and IG2 ($p < 0.001$) and between IG1 and IG2 ($p = 0.024$) (refer to Table 17). The perceived stress score of IG2 was significantly lower than those of the other two groups, indicating that open-skill exercise was the most effective in reducing perceived stress.

Table 17. Between-group simple effects of perceived stress at pre-test and post-test

Time	Group Comparison	Mean Difference	SE	t	p
Pre-test	CG vs. IG1	-0.090	0.200	-0.450	0.894
Pre-test	CG vs. IG2	0.055	0.200	0.275	0.959
Pre-test	IG1 vs. IG2	0.145	0.200	0.725	0.749
Post-test	CG vs. IG1	0.385	0.200	1.925	0.137
Post-test	CG vs. IG2	0.920	0.200	4.601	< 0.001
Post-test	IG1 vs. IG2	0.535	0.200	2.675	0.024

The within-group results showed (refer to Table 18) that there was no significant change in perceived stress between the pre-test and post-test in the CG ($p = 0.410$), indicating that the level of perceived stress remained generally stable in the absence of intervention. In contrast, significant pre-test to post-test differences were observed in both IG1 and IG2 ($p < 0.001$), suggesting that both closed-skill and open-skill exercise were effective in reducing perceived stress. As shown in Fig.5, IG2 demonstrated the greatest reduction, further indicating that open-skill exercise had a stronger effect on alleviating perceived stress.

Table 18. Within-group simple effects of perceived stress over time

Group	Time Comparison	Mean Difference	SE	t	p
CG	Pre-test vs. Post-test	0.120	0.145	0.830	0.410
IG1	Pre-test vs. Post-test	0.595	0.145	4.116	< 0.001
IG2	Pre-test vs. Post-test	0.985	0.145	6.813	< 0.001

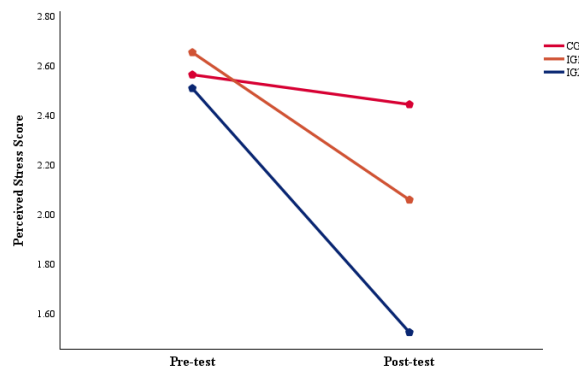


Fig.5. Changes in perceived stress across groups from pre-test to post-test

Discussion

This study employed a quasi-experimental design to examine the effects of open-skill and closed-skill exercise on physical fitness, emotional well-being, and perceived stress among university students. Based on the findings, the following sections discuss these results from the three perspectives outlined above.

The findings of this study showed that both open-skill and closed-skill exercise significantly improved the physical fitness of university students, and both performed better than the CG. However, no significant difference was found between the two intervention groups before and after the intervention, indicating that different types of exercise can effectively improve the physical fitness of university students. This finding is consistent with previous research. For example, one study reported that a 12-week Baduanjin intervention could significantly improve the physical fitness of university students (Ye, Zhao, Sun, Xiong, & Zheng, 2022). Similar results have also been reported in other Baduanjin intervention studies conducted among female university students (Li et al., 2015; Zhao, Nan, & Xing, 2024). A 30-week extracurricular running program was likewise found to significantly improve the physical fitness of university students (Liang & Wu, 2024). In addition, a cluster randomized controlled trial of basketball instruction showed that a 16-week intervention effectively enhanced university students' physical fitness levels (C. Wang, Yuan, & Ji, 2024). Taken together, these findings suggest that both open-skill and closed-skill exercise can significantly improve the physical fitness of university students.

This study also found that university students in the CG showed a significant improvement from pre-test to post-test ($p < 0.05$), a result that has also been reported in some previous studies (C. Wang et al., 2024). This finding may be related to the educational goals of university students in China. At present, higher education institutions generally place emphasis on the all-round development of students in terms of moral, intellectual, physical, aesthetic, and labor education (Peipei & Xue, 2025), while physical education curricula, the National

Student Physical Health Standard (NSPHS), and campus sports culture together create a relatively stable environment for physical activity. Therefore, even without a specific intervention, students in the CG may still obtain certain physical and psychological benefits. Accordingly, when the extent of change in each group is taken into account, both open-skill and closed-skill exercise can be considered effective in improving the physical fitness of university students.

In this study, both open-skill and closed-skill exercise were found to improve emotional well-being in university students, as reflected by increased positive affect and reduced negative affect. A study published in 2024 reported that a certain level of physical activity can directly influence students' emotional states (Mu et al., 2024), and that physical activity is also indirectly associated with reductions in negative emotions (M. Liu et al., 2024). In addition, an 8-week intervention study involving adolescent girls found that closed-skill exercise could significantly reduce negative emotions (Qian Gu et al., 2024). These findings are consistent with the results of the present study. Furthermore, this study found that open-skill exercise was superior to closed-skill exercise in both enhancing positive affect and reducing negative affect, suggesting that the form of exercise itself may influence the magnitude of emotional benefits. However, some studies have reported different findings. In one such study, closed-skill exercise was found to be significantly more effective than open-skill exercise in improving emotions. This discrepancy may be mainly attributable to differences in the exercise modes adopted in the interventions. Nevertheless, regardless of the specific factors involved, the findings consistently indicate that both types of exercise can effectively improve the emotional well-being of university students.

The findings of this study showed that both open-skill and closed-skill exercise significantly reduced perceived stress among university students. No significant differences were found among the three groups at the pre-test stage, whereas after the intervention, the perceived stress score of the open-skill group was significantly lower than those of the closed-skill group and the CG, indicating that open-skill exercise was more effective in reducing perceived stress in university students. Previous research has shown that low- to moderate-intensity aerobic exercise interventions can effectively improve perceived stress among university students (Herbert, 2022). Another study on Tai Chi also reported that Tai Chi had a positive effect on reducing students' stress (Dinani, Mehrabi, & Sadeghi, 2019). In addition, mindfulness training (Gallego, Aguilar-Parra, Cangas, Langer, & Mañas, 2014) and yoga training (Gao et al., 2022) have also been found to significantly reduce students' perceived stress. Furthermore, a study involving 64 doctoral students found that, compared with Tai Chi as a single closed-skill exercise, a combined exercise approach integrating both open-skill and closed-skill exercise showed a more sustained effect on improving perceived stress (Wu, Yang, Jiang, Yu, & Jin, 2025). To some extent, this suggests that, compared with a single exercise form, intervention programs that integrate multiple exercise characteristics may be more beneficial for stress management. Based on this, future studies may further explore the long-term value of combined exercise interventions in improving perceived stress among university students after establishing the effectiveness of single exercise interventions.

Conclusion

This study employed a quasi-experimental design to compare the effects of open-skill and closed-skill exercise on physical fitness, emotional well-being, and perceived stress among university students. The results showed that both types of exercise interventions significantly improved physical fitness and had a positive impact on emotional well-being and perceived stress, indicating that both open-skill and closed-skill exercise are valuable in promoting the physical and mental health development of university students.

Further comparisons revealed that both types of exercise had a significant effect on improving physical fitness, but no significant between-group differences were observed, suggesting that both types of exercise effectively promote the development of physical fitness. However, in terms of emotional well-being and perceived stress, open-skill exercise was more effective than closed-skill exercise, indicating that open-skill exercise may have greater potential in improving university students' mental health.

Overall, this study confirms that different types of exercise interventions have a positive impact on the physical and mental health of university students, with open-skill exercise showing particular advantages in promoting mental health. Future research could further explore combined intervention models incorporating both open-skill and closed-skill exercise to assess their sustained effects and practical value in promoting the physical and mental health of university students.

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