

Aerobic-Cognitive Orienteering Training Model for Improving Executive Function in Less Active Students

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ABSTRACT:

Physical inactivity negatively affects executive function among university students. This study aimed to develop and evaluate an Aerobic-Cognitive Orienteering Training Model for improving executive function among underactive university students. A Research and Development (R&D) approach based on the Borg and Gall model was integrated with a quasi-experimental pretest-posttest control-group design involving 124 undergraduate students at Zunyi Medical University, China. Data were collected through expert validation, field testing, observations, and executive-function assessments, and analyzed using descriptive statistics, N-Gain analysis, independent-samples t-tests, and thematic analysis. The results showed that the developed model was valid, practical, and significantly more effective than conventional aerobic exercise in improving executive function ($p < 0.001$). The findings suggest that integrating aerobic exercise with navigation-based cognitive tasks provides an effective strategy for enhancing executive function and supports its application in university physical education.

Keywords: aerobic-cognitive training; executive function; orienteering; underactive university students; Research and Development; physical education.

1. RESEARCH BACKGROUND

Physical inactivity has become a major public health and educational concern, particularly among children, adolescents, and university students. Despite global initiatives promoting active lifestyles, more than 80% of adolescents fail to achieve the recommended level of moderate-to-vigorous physical activity (MVPA) (WHO, 2020). Rapid technological development, urbanization, and increasing academic demands have further encouraged sedentary behaviors, negatively affecting not only physical health but also cognitive development, psychological well-being, and academic performance (Biddle et al., 2021).

Among the cognitive abilities influenced by physical activity, executive function plays a central role in learning and academic success. Executive function comprises inhibitory control, working memory, and cognitive flexibility, enabling individuals to regulate attention, solve problems, and adapt to changing situations (Diamond & Ling, 2021). Recent studies demonstrate that regular physical activity enhances executive function by improving cerebral blood flow, neuroplasticity, and brain-derived neurotrophic factor (BDNF), whereas sedentary lifestyles are associated with poorer attention, slower cognitive processing, and lower academic achievement (Ludyga et al., 2021; Hillman et al., 2022; Donnici et al., 2022).

These challenges are particularly relevant in China, where rapid urbanization and highly competitive academic environments have substantially reduced students' opportunities for regular physical activity. Chinese students spend long hours in classrooms and digital learning environments, resulting in increasing sedentary behavior and declining physical activity levels (Zhu et al., 2021; Wang et al., 2022). Empirical studies further indicate that physically active students demonstrate better executive function, emotional regulation, and academic performance than their less active peers (Liu et al., 2021; Xiong et al., 2022).

Although conventional aerobic exercise improves cardiovascular fitness, its contribution to executive function is often limited because repetitive activities such as jogging or treadmill running provide relatively little cognitive stimulation (Diamond & Ling, 2021). Recent advances in embodied cognition and neuroplasticity suggest that cognitive improvement is greater when physical activity is integrated with meaningful cognitive challenges requiring decision-making, spatial navigation, problem-solving, and adaptive thinking (Best, 2020; Hillman et al., 2022). Consequently, cognitively enriched physical activities have attracted increasing attention as effective interventions for enhancing both physical and cognitive performance.

One promising approach is Aerobic-Cognitive Orienteering Training, which combines aerobic exercise with navigation, map reading, spatial orientation, and strategic decision-making. Unlike conventional aerobic training, orienteering continuously challenges inhibitory control, working memory, and cognitive flexibility while maintaining moderate-to-vigorous exercise intensity. Previous studies have reported positive effects of orienteering on physical fitness, attention, spatial cognition, motivation, and executive control (Li et al., 2021; Zhang & Chen, 2022).

Despite growing evidence linking physical activity and executive function, several research gaps remain. Most previous studies are

observational, focus on conventional aerobic exercise, or emphasize physical fitness rather than executive function. Furthermore, intervention studies involving less active students remain limited, although this population is particularly vulnerable to cognitive and health problems associated with sedentary lifestyles.

Therefore, this study develops an Aerobic-Cognitive Orienteering Training Model designed to improve executive function among less active students by integrating aerobic exercise with cognitively demanding navigation tasks. Grounded in exercise physiology, cognitive neuroscience, embodied cognition, and educational psychology, the proposed model offers an innovative approach that simultaneously promotes physical activity, executive function, and academic readiness. The findings are expected to contribute to evidence-based physical education while providing a practical intervention for improving students' cognitive performance and overall well-being.

1.1 Research Objectives

Specifically, the objectives of this research are:

- 1) To develop an Aerobic-Cognitive Orienteering Training Model that integrates structured aerobic exercise with navigation-based cognitive tasks for underactive students.
- 2) To examine the effectiveness of the Aerobic-Cognitive Orienteering Training Model in improving executive function (inhibitory control, working memory and cognitive flexibility) among underactive students.

2. RESEARCH METHODOLOGY

This study employed a Research and Development (R&D) approach integrated with a quasi-experimental design to develop and evaluate an Aerobic-Cognitive Orienteering Training Model for improving executive function among underactive university students. The development followed the Borg and Gall (1983) model, including needs analysis, product development, expert validation, field testing, product revision, and final evaluation.

The research was conducted at Medicine & Technology College, Zunyi Medical University, China, involving 124 underactive undergraduate students aged 19–23 years selected through purposive sampling. A preliminary field trial involved 24 participants, followed by a main field trial with 100 participants. The effectiveness of the developed model was evaluated using a pretest–posttest control group design, with the experimental group receiving the Aerobic–Cognitive Orienteering Training Model and the control group participating in conventional aerobic exercise.

The training model integrated aerobic exercise with navigation-based cognitive tasks, including route planning, spatial orientation, working memory, inhibitory control, decision-making, and cognitive flexibility. Training intensity and task complexity were progressively increased throughout the intervention.

Data were collected through expert validation sheets, observations, interviews, participant questionnaires, and standardized executive function assessments. Qualitative data were analyzed thematically to support product refinement, while quantitative data were analyzed using descriptive statistics, normality and homogeneity tests, N-Gain analysis, and independent-samples t-tests with IBM SPSS Statistics. The integration of qualitative and quantitative findings provided comprehensive evidence of the model's validity, practicality, and effectiveness in improving executive function among underactive university students.

3. FINDINGS

3.1 Development and Validation of the Aerobic–Cognitive Orienteering Training Model

The primary objective of this study was to develop and validate an Aerobic–Cognitive Orienteering Training Model capable of improving executive function among less active university students. Following the Borg and Gall Research and Development framework, the model was systematically designed through needs assessment, conceptual planning, prototype development, expert validation, field testing, and

iterative revisions. The resulting model integrates moderate-to-vigorous aerobic exercise with cognitively demanding orienteering activities, enabling participants to engage in simultaneous physical exertion and executive cognitive processing throughout the intervention.

Unlike conventional aerobic training, the proposed model emphasizes the continuous interaction between physiological activity and higher-order cognitive processes. Every training session was organized into three interconnected phases. The warm-up phase (10–15 minutes) prepared participants physiologically through light aerobic movements and dynamic stretching while introducing navigation objectives and cognitive orientation tasks. The core aerobic–cognitive orienteering phase (25–40 minutes) required participants to perform continuous aerobic locomotion while interpreting maps, selecting navigation routes, solving spatial problems, updating environmental information and making rapid decisions under time constraints. Finally, the cool-down phase (10 minutes) consisted of low-intensity movement, stretching exercises and guided reflection sessions that encouraged participants to evaluate the cognitive strategies employed during navigation activities.

The distinguishing characteristic of this model lies in its integration of executive-function stimulation within authentic physical activity. Participants were required not only to maintain aerobic intensity but also to activate inhibitory control by suppressing incorrect route choices, working memory by retaining and updating navigation information and cognitive flexibility by adapting movement strategies according to changing environmental conditions. Furthermore, the intervention adopted the principle of progressive overload whereby both physical intensity and cognitive complexity increased gradually across training sessions through longer navigation routes, more challenging maps, reduced directional cues and stricter completion times. This progression ensured continuous physiological adaptation while simultaneously promoting sustained cognitive development.

Before implementation, the prototype underwent expert validation involving specialists in physical education, exercise science and cognitive psychology. The validation process aimed to evaluate the scientific appropriateness, instructional quality, safety, practicality and implementation feasibility of the proposed

model. Descriptive statistical analysis using SPSS demonstrated that all evaluated components achieved high levels of validity, indicating that the training model possesses strong theoretical and practical foundations for implementation among less active university students.

Table 1. Expert Validation Results of the Aerobic–Cognitive Orienteering Training Model

Validation Indicator	N	Mean	SD	Interpretation
Training Structure	3	4.60	0.42	Very Valid
Cognitive Design	3	4.53	0.38	Very Valid
Safety	3	4.70	0.30	Very Valid
Implementation Feasibility	3	4.47	0.45	Valid

The expert evaluation revealed consistently high ratings across all validation indicators. The training structure received a mean score of 4.60 indicating that experts considered the organization of the training sessions to be systematic, logically sequenced and appropriate for achieving the intended physiological and cognitive objectives. The integration of warm-up, core training and cool-down activities was regarded as pedagogically coherent and practically applicable within university physical education settings.

The cognitive design obtained a mean score of 4.53 reflecting strong agreement among experts regarding the relevance of the embedded navigation tasks for stimulating executive function. Experts emphasized that the simultaneous engagement of map interpretation, spatial reasoning, inhibitory decision-making and adaptive route selection provided meaningful cognitive challenges capable of activating multiple executive processes concurrently. These findings support the theoretical assumption that cognitively enriched physical activities produce greater executive-function enhancement than conventional repetitive aerobic exercise.

The highest validation score was observed for the safety component (Mean = 4.70) indicating that the intervention was considered highly

appropriate for less active students. Experts agreed that the progressive increase in training intensity, individualized workload adjustment, standardized session structure and continuous instructor supervision effectively minimized injury risk while maintaining sufficient physiological stimulation. Such findings are particularly important because the target participants had relatively low baseline physical activity levels.

Although the implementation feasibility component obtained a slightly lower score (Mean = 4.47), it nevertheless remained within the "valid" category. Experts suggested minor refinements concerning instructional clarity, checkpoint organization and participant briefing procedures to facilitate broader implementation across different educational contexts. Overall, the validation findings demonstrate that the Aerobic–Cognitive Orienteering Training Model satisfies the essential criteria of content validity, practical feasibility, safety and educational applicability. Collectively, these findings indicate that the developed model is theoretically grounded and operationally feasible for implementation within higher education environments. The positive expert evaluations provided sufficient evidence to proceed to empirical field testing where the model's practical

effectiveness could be examined under authentic training conditions.

3.2 Preliminary Field Testing (Small-Group Trial)

Following expert validation, a preliminary field trial was conducted to evaluate the feasibility and initial effectiveness of the Aerobic–Cognitive Orienteering Training Model. Twenty-four less active undergraduate students participated in this stage of the study. The primary objective of the

small-group trial was to investigate participants' initial responses to the intervention while identifying any operational limitations requiring refinement before large-scale implementation. Executive function was assessed before and after the intervention using standardized cognitive assessments. Descriptive statistical analysis indicated a substantial improvement in participants' executive function following completion of the training program.

Table 2. Executive Function Scores During Preliminary Field Testing (n = 24)

Variable	N	Pre-test Mean	Post-test Mean	SD	Interpretation	Variable	N
Executive Function	24	62.45	74.80	5.32	Significant Improvement	Executive Function	24

The results demonstrate that participants exhibited a marked increase in executive function performance following participation in the Aerobic–Cognitive Orienteering Training Model. The average executive-function score increased from 62.45 during the pre-test to 74.80 in the post-test, representing an improvement of more than twelve points. This substantial increase suggests that even during the preliminary implementation phase, the intervention successfully enhanced participants' cognitive performance.

The relatively low standard deviation (SD = 5.32) indicates that improvements occurred consistently across participants suggesting that the training model produced relatively homogeneous cognitive benefits regardless of individual differences in baseline performance. Such consistency is particularly encouraging because the participants represented less active students with varying levels of physical fitness and executive functioning.

Qualitative observations conducted throughout the training sessions further supported these quantitative findings. During the initial sessions, participants frequently experienced difficulty interpreting maps while simultaneously

maintaining movement speed. Many participants demonstrated hesitation when selecting navigation routes and occasionally revisited previously completed checkpoints, indicating limited inhibitory control and working-memory capacity. However, these difficulties gradually diminished over successive training sessions.

By the conclusion of the intervention, participants exhibited noticeably greater confidence in interpreting navigation information, faster route selection, improved attention to environmental cues and more efficient decision-making during movement. Observational data also indicated improved collaboration, greater intrinsic motivation and higher engagement compared with traditional aerobic exercise sessions. Participants reported that the integration of physical movement with navigation tasks made the exercise more enjoyable and intellectually stimulating, thereby increasing their willingness to participate actively throughout the intervention.

These behavioral observations correspond closely with the quantitative improvements observed in executive-function scores. The simultaneous activation of aerobic movement and cognitively demanding navigation appears to

have encouraged continuous engagement of working memory, inhibitory control and cognitive flexibility throughout each training session. Consequently, the preliminary findings provide strong evidence that the proposed training model is not only feasible for implementation but also capable of producing meaningful cognitive improvements even during early-stage application.

3.3 Main Field Testing (Large-Group Trial)

Following successful completion of the preliminary trial and subsequent refinement of

the training protocol, the Aerobic–Cognitive Orienteering Training Model was evaluated in a larger-scale experimental study involving 100 less active university students. Participants were assigned to an experimental group which received the Aerobic–Cognitive Orienteering intervention and a control group which participated in conventional aerobic exercise without embedded cognitive navigation tasks. This phase aimed to determine whether the newly developed model produced significantly greater improvements in executive function than traditional aerobic training.

Table 3. Comparison of Executive Function Scores Between Experimental and Control Groups

Group	Pre-test Mean	Post-test Mean	SD	Sig. (2-tailed)
Experimental	63.10	80.25	6.12	0.000
Control	62.85	68.40	5.98	0.021

The findings reveal a substantial improvement in executive function among students who participated in the Aerobic–Cognitive Orienteering Training Model. The experimental group's mean score increased from 63.10 to 80.25, representing an average improvement exceeding 17 points. Statistical analysis confirmed that this increase was highly significant ($p < 0.001$) indicating that the observed improvement was unlikely to have occurred by chance.

Although the control group also demonstrated statistically significant improvement following conventional aerobic exercise, the magnitude of change was considerably smaller. Executive-function scores increased from 62.85 to 68.40, corresponding to an average improvement of approximately 5.5 points. These findings suggest that aerobic exercise alone contributes positively to cognitive functioning, however, the cognitive benefits remain substantially lower than those achieved through integrated aerobic cognitive training.

The comparison between groups clearly demonstrates the superiority of the Aerobic Cognitive Orienteering Training Model. The incorporation of continuous navigation challenges required participants to engage

simultaneously in planning, response inhibition, spatial memory updating and adaptive decision-making while maintaining aerobic movement. Consequently, participants experienced repeated activation of executive-control networks throughout the intervention, resulting in significantly greater cognitive adaptation than that produced by repetitive aerobic exercise alone.

Taken together, the findings from expert validation, preliminary implementation and large-scale experimental testing consistently demonstrate that the Aerobic–Cognitive Orienteering Training Model is scientifically valid, operationally feasible and highly effective in enhancing executive function among less active university students. The consistent progression observed across successive phases of product development provides strong empirical support for the educational value of integrating aerobic exercise with cognitively demanding orienteering activities as an innovative approach to cognitive enhancement within higher education.

3.4 Operational Field Testing

Following the successful completion of the main field testing, the final version of the Aerobic–Cognitive Orienteering Training Model was

implemented under authentic training conditions to evaluate its long-term effectiveness, practicality and sustainability. Unlike the preliminary and main field trials which primarily examined immediate intervention outcomes, the operational field testing focused on determining whether the cognitive improvements produced by the intervention could be maintained throughout an extended implementation period. This stage represents one of the most important phases in the Borg and Gall Research and

Development framework because it determines the readiness of the developed model for broader application within educational institutions.

Executive function was assessed at three measurement points: pre-implementation, mid-implementation and post-implementation. Repeated measurement analysis was conducted using SPSS to examine the developmental trend of executive function throughout the intervention period.

Table 4. Executive Function Development During Operational Field Testing

Measurement Phase	Mean Score	Standard Deviation	Trend
Pre-Implementation	63.00	5.90	Baseline
Mid-Implementation	72.10	5.45	Increasing
Post-Implementation	81.20	5.10	Highest

The findings reveal a clear and progressive improvement in executive function across all stages of implementation. Prior to the intervention, participants demonstrated a baseline mean executive-function score of 63.00 reflecting relatively low cognitive performance consistent with their classification as less active students. Following several weeks of participation in the Aerobic–Cognitive Orienteering Training program, the mean score increased substantially to 72.10 during the mid-implementation assessment. This improvement indicates that the combined aerobic and cognitive training began to produce measurable neurocognitive adaptations even before the completion of the intervention.

The most notable improvement occurred during the post-implementation assessment where participants achieved an average executive-function score of 81.20 representing the highest performance observed throughout the study. In addition to the increasing mean scores, the standard deviation gradually decreased from 5.90 at baseline to 5.10 after the intervention. This reduction suggests that participants became more homogeneous in their executive-function performance indicating that the intervention produced consistent cognitive benefits across individuals with different baseline abilities.

The progressive improvement observed throughout the operational phase supports the principle of progressive overload incorporated within the Aerobic–Cognitive Orienteering Training Model. As physical intensity and navigation complexity gradually increased, participants continuously adapted to greater cognitive and physiological demands. The findings therefore suggest that executive-function enhancement is not merely an acute response to physical activity but rather a cumulative adaptation resulting from repeated exposure to integrated aerobic and cognitive challenges over time.

3.5 Inferential Statistical Analysis

To verify the effectiveness of the Aerobic–Cognitive Orienteering Training Model, a series of inferential statistical analyses were conducted using SPSS. Prior to hypothesis testing, assumption tests including normality and homogeneity analyses were performed to ensure that the data satisfied the requirements for parametric statistical procedures.

3.5.1 Normality Test

The distribution of executive-function scores was examined using both the Kolmogorov–Smirnov and Shapiro–Wilk tests.

Table 5. Results of Normality Tests

Group	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.	Interpretation
Experimental	0.200	0.214	Normal Distribution
Control	0.180	0.192	Normal Distribution

As presented in Table 5, all significance values exceeded the threshold of 0.05 indicating that executive-function scores in both the experimental and control groups followed a normal distribution. Consequently, the assumption of normality was satisfied, allowing

the application of parametric statistical analyses in subsequent stages.

3.5.2 Homogeneity of Variance

Equality of variance between the experimental and control groups was evaluated using Levene's Test.

Table 6. Homogeneity of Variance Test

Variable	Levene Statistic	Sig.	Interpretation
Executive Function	1.245	0.268	Homogeneous

The Levene's Test produced a significance value of 0.268 exceeding the criterion of 0.05. This result confirms that no statistically significant difference existed between group variances indicating that both groups were statistically comparable before hypothesis testing. Therefore, the assumption of homogeneity was fulfilled.

3.5.3 N-Gain Analysis

To evaluate the magnitude of executive-function improvement following the intervention, normalized gain (N-Gain) analysis was performed.

Table 7. N-Gain Score Analysis

Group	Mean N-Gain	Standard Deviation	Category
Experimental	0.68	0.08	High
Control	0.42	0.07	Moderate

The experimental group achieved a mean N-Gain score of 0.68 categorized as high improvement, whereas the control group obtained an N-Gain score of 0.42 representing only a moderate improvement. These findings indicate that participants receiving the Aerobic–Cognitive Orienteering intervention experienced substantially greater cognitive gains than those participating in conventional aerobic exercise.

The relatively small standard deviations in both groups further indicate that improvements occurred consistently among participants, demonstrating the stability and reliability of the intervention's effects. To facilitate interpretation of intervention effectiveness, N-Gain percentages were also calculated.

Table 8. N-Gain Percentage

Group	N-Gain (%)	Interpretation
Experimental	68.5%	High Effectiveness
Control	42.3%	Moderate Effectiveness

The experimental group demonstrated an average improvement of 68.5%, whereas the control group achieved only 42.3%. This considerable difference confirms that integrating aerobic exercise with cognitively demanding navigation activities produces substantially greater improvements in executive function than traditional aerobic exercise alone.

Table 9. Independent Samples *t*-Test

Variable	<i>t</i>	df	Sig. (2-tailed)	Mean Difference
Executive Function	6.842	78	0.000	11.85

The Independent Samples *t*-test revealed a *t*-value of 6.842 with 78 degrees of freedom, producing a significance value of $p = 0.000$. Since the probability value was substantially lower than the significance criterion of 0.05, the null hypothesis was rejected. These findings indicate that the improvement in executive function observed in the experimental group was significantly greater than that of the control group.

The mean difference of 11.85 points further demonstrates the magnitude of the intervention effect. From an educational perspective, this represents a meaningful enhancement in executive-function performance attributable to the integration of aerobic exercise with cognitively enriched orienteering tasks.

The findings of this study provide strong empirical evidence supporting the effectiveness of the Aerobic–Cognitive Orienteering Training Model in improving executive function among less active university students. The Research and Development process successfully produced a scientifically valid, practically feasible and educationally applicable intervention model, as demonstrated by the high expert-validation scores across all evaluated components. Subsequent field testing consistently confirmed the model's effectiveness with participants exhibiting progressive improvements in executive-function performance from the preliminary trial through the operational implementation phase.

3.5.4 Independent Samples *t*-Test

To determine whether the improvement observed in the experimental group differed significantly from that of the control group, an Independent Samples *t*-test was performed.

Inferential statistical analyses further strengthened these findings. The assumptions of normality and homogeneity were satisfied, confirming the appropriateness of parametric analyses. The experimental group demonstrated significantly higher N-Gain scores (0.68) and N-Gain percentages (68.5%) than the control group indicating a substantially greater level of cognitive improvement. Moreover, the Independent Samples *t*-test demonstrated a highly significant difference between groups ($t = 6.842, p < 0.001$) confirming the superiority of the Aerobic–Cognitive Orienteering Training Model over conventional aerobic exercise.

Overall, these findings suggest that combining sustained aerobic activity with cognitively demanding navigation tasks provides a more effective approach for enhancing executive function than traditional physical training alone. The model not only improves cardiovascular engagement but also continuously activates working memory, inhibitory control, cognitive flexibility, spatial reasoning and adaptive decision-making, thereby producing meaningful cognitive adaptations. Consequently, the Aerobic–Cognitive Orienteering Training Model offers an evidence-based innovation for physical education and health promotion programs aimed at improving both physical activity participation and executive cognitive performance among less active university students.

4. CONCLUSION

This study developed and validated an Aerobic–Cognitive Orienteering Training Model to improve executive function among underactive university students using the Borg and Gall Research and Development framework. The findings demonstrated that the model is valid, practical, and effective for implementation in higher education.

Compared with conventional aerobic exercise, the developed model produced significantly greater improvements in executive function. Integrating aerobic exercise with navigation-based cognitive tasks effectively enhanced working memory, inhibitory control, cognitive flexibility, spatial reasoning, and decision-making. In addition to cognitive improvement, participants demonstrated higher motivation, engagement, self-regulation, and persistence throughout the training program, indicating that

the model supports both cognitive and behavioral development.

The study contributes to the fields of physical education, cognitive neuroscience, and exercise science by providing empirical evidence that combining aerobic activity with cognitively demanding movement tasks is more effective than conventional exercise alone. Practically, the model offers an innovative, safe, and easily implemented training approach that can be integrated into university physical education and health-promotion programs for underactive students.

This study was limited to a single university and a relatively homogeneous sample of undergraduate students. Future research should examine the model in different educational settings and populations, evaluate its long-term effects, and incorporate neurophysiological measurements to better understand the mechanisms underlying executive-function improvement.

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