ORIGINAL ARTICLE

The effect of modified brain break warm-up on executive functions, attentional refocusing, and mood states in collegiate e-sports players: An exploratory proof-of-concept randomized controlled trial

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ABSTRACT

Competitive esports impose prolonged cognitive loads under intense psychological pressure, frequently precipitating acute mental fatigue and attentional lapses. This exploratory proof-of-concept randomized controlled trial examined the acute effects of a tailored, 5-minute Modified Brain Break Warm-up (MBBW) program on cognitive readiness, executive functions, attentional refocusing, and transient mood states in collegiate esports players. Methods: A randomized controlled trial compared players utilizing the MBBW program (experimental group, n=15) against a conventional warm-up (control group, n=15). The MBBW consisted of a 12-movement structured, closed-skill curriculum paced to a moderate-tempo soundtrack (100–105 BPM). Participants were assessed pre- and post-intervention on executive functions (task shifting, working memory, and inhibitory control via the Stroop Test), attentional refocusing, and transient mood states using the Thai Athlete Mood Scale (TAMS). Results: The MBBW group demonstrated statistically significant, high-magnitude improvements compared to the control group in task shifting (d = 0.82, p < .001) and working memory updating (p < .001). The most substantial positive impact was observed in attentional refocusing ability (d = 1.16, p < .001). Under high cognitive conflict, the MBBW group achieved significantly faster reaction times (Stroop Incongruent RT: d = 0.54, p = .004). Furthermore, the intervention elicited significant reductions in negative affect, notably subjective fatigue (d = 0.89, p < .001), while maintaining a stable, non-hyperaroused state of vigour (p = .085). Conclusion: A brief 5-minute movement-based warm-up provides promising preliminary evidence for mitigating acute cognitive resource depletion and stabilizing emotional readiness prior to competitive gaming. Although objective in-game performance metrics warrant further empirical validation, this time-efficient kinetic protocol serves as a feasible pre-performance routine. Moreover, its ergonomic architecture offers valuable translational utility as a physical micro-break to counteract sedentary fatigue and cognitive stagnation across university classrooms and desk-based learning environments.
Keywords: sport medicine, brain break, warming up, e-sport, executive function, mood state, attentional refocusing.

Cite this article as:
Sritubtim, P., Julavanichpong, T., Kuan, G., Suksawang, P., Chang, Y.-K., & Singnoy, C. (2027). The effect of modified brain break warm-up on executive functions, attentional refocusing, and mood states in collegiate e-sports players: An exploratory proof-of-concept randomized controlled trial. *Journal of Human Sport and Exercise, 22*(1), 353-372. https://doi.org/10.55860/kfkj0g41

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Submitted for publication September 24, 2026.
Accepted for publication November 02, 2026.
Published November 24, 2026.
Journal of Human Sport and Exercise. ISSN 1988-5202.
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doi: https://doi.org/10.55860/kfkj0g41

INTRODUCTION

In the contemporary era, electronic sports (E-sports) have transitioned from recreational leisure activities into highly structured, high-stakes competitive domains (Gong et al., 2019; Hagiwara et al., 2019). Particularly in collegiate E-sports, these platforms function as rigorous Cognitive Training Environments that mirror, and often exceed, the psychological demands of traditional sports. Elite performance in this domain necessitates robust executive functions (EF), strategic thinking, and precise psychomotor coordination (Zanini et al., 2018). While intensive competition facilitates positive neural plasticity within brain regions associated with executive control, the prolonged and high-pressure nature of E-sports subjects' players to extreme cognitive loads (Gong et al., 2019). This intensity frequently induces “cognitive overload” and acute mental fatigue, which creates a bottleneck in cognitive resources, ultimately manifesting as delayed reaction times, attentional lapses, and compromised decision-making (Lopes de Lima et al., 2025; Sun et al., 2021).

Despite these severe cognitive and emotional demands, there remains a conspicuous lack of specialized warm-up programs that integrate both physical and psychological preparation within the restrictive 10-to-15-minute timeframe typically available before competitive matches (Hagiwara et al., 2019). Traditional warm-ups in E-sports predominantly focus on localized physical preparation (e.g., wrist and finger stretching), largely neglecting the neurological and cognitive readiness of the athlete. Furthermore, E-sports players face prolonged sedentary stress and repetitive movements, contributing to accumulated mental fatigue that can lead to rapid burnout and emotional volatility during play (DiFrancisco-Donoghue et al., 2019). Consequently, managing acute mental fatigue and emotional states through an application-based, time-efficient performance enhancement tool is critical to optimizing players’ cognitive readiness (Albulescu et al., 2022; Yu et al., 2025).

Default Mode Network involvement remains a theoretical possibility rather than a mechanism demonstrated by the present behavioural trial. A promising theoretical framework for mitigating these cognitive stressors is rooted in the link between emotions, neurological recovery, and learning (Immordino-Yang & Damasio, 2007). In educational and higher education settings, "Brain Breaks"—short, structured intervals of rest or activity—have emerged as a critical strategy to reduce stress, boredom, and restlessness while enhancing focus and psychological well-being (Keating et al., 2022; Peiris et al., 2021). From a neurophysiological perspective, shifting away from high-cognitive-load tasks facilitates recovery from mental fatigue by shifting autonomic nervous system activity and increasing Default Mode Network (DMN) activity (Thomson et al., 2015). The activation of the DMN is essential for cognitive restoration, creative problem-solving, and the resetting of executive functions (Dijksterhuis et al., 2006).

To adapt the Brain Break concept for elite athletic performance, the integration of specific motor and sensory stimuli is required. Research indicates that the implementation of "closed-skill exercises"—structured physical movements performed in a predictable environment—can effectively channel attention and stabilize arousal. When coupled with rhythmic music at a moderate tempo (100–105 bpm), these exercises have been proven to synergistically induce a state of "calm alertness," which is highly conducive to optimal performance under pressure (Gu et al., 2019; Karageorghis et al., 2006). Despite these established neurocognitive benefits, the tailored application of structured Brain Breaks to address the unique sedentary and cognitive stressors of E-sports players remains completely unexplored.

To address this critical gap, the present study developed a tailored "Modified Brain Break Warm-up" (MBBW) program designed specifically for E-sports players using a rigorous Research and Development (R&D) approach. This 5-minute digital intervention consists of 12 ergonomically and cognitively designed

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movements tailored to the specific psychomotor demands of competitive gamers. Therefore, this research aims to evaluate the feasibility of the MBBW program and systematically investigate its acute effects on executive function, attentional refocusing ability, and mood states among collegiate E-sports players.

Research questions and hypotheses

Based on the identified gaps, this study addresses two primary questions:

1. Can an ergonomically tailored MBBW program be successfully developed and validated for E-sports?
2. Does a 5-minute MBBW intervention produce significant acute improvements in the cognitive and emotional states of players?

We hypothesize that the MBBW program will result in significant post-intervention improvements in refocusing ability, inhibitory control, and cognitive flexibility, while simultaneously reducing negative mood states (anger, fatigue, and confusion).

Literature review and operational definitions

Operationalization of key terms

To ensure clarity, key concepts are operationalized as follows:

- Executive Function (EF): In this study, EF refers specifically to the top-down mental processes of *inhibitory control* (resisting impulsive reactions), *cognitive flexibility* (shifting between strategies), and *working memory* (holding and manipulating game information).
- Cognitive Fatigue: Defined as the decline in cognitive resources resulting from prolonged periods of intense mental effort, characterized by decreased reaction times and increased error rates in decision-making.

Theoretical framework

This study builds upon Attention Restoration Theory (ART), which suggests that environments or activities that do not require "directed attention" allow the brain's focused-attention mechanisms to recover. By shifting the athlete's focus from a digital screen to rhythmic, physical movements (Closed-skill exercise), the MBBW program acts as a restorative stimulus.

METHODOLOGY

Participants and sampling

Sample size calculation

To determine the required sample size, an a priori power analysis was conducted using G*Power software (Version 3.1.9.7). Based on general educational Brain Break literature reporting large effects (e.g., d = 1.06), an initial calculation suggested N = 30. However, recognizing that acute cognitive shifts in specialized esports contexts may yield more nuanced effects, this study is explicitly designated as a preliminary exploratory proof-of-concept study (n = 15 per group, total N = 30). Sensitivity analyses indicated that with N = 30 (alpha = .05, power = .80), the design is powered to reliably detect medium-to-large effects ($\mathrm{n}_{\mathrm{p}}^{2} \geq 0.14$). The primary aim of this trial is to evaluate feasibility, estimate parameter variance, and establish proof-of-concept rather than provide definitive efficacy benchmarks.

Participant recruitment and stratification

Participants were recruited using a volunteer sampling strategy through digital advertisements posted on official university E-sports club channels and prominent Thai collegiate E-sports community pages on social

media platforms. A cohort of university E-sports players initially expressed interest in the study. Following a rigorous screening process based on the inclusion and exclusion criteria, the final sample comprised *N* = 30 collegiate E-sports players who actively competed in major E-sports titles, specifically Realm of Valor (ROV), Player Unknown's Battlegrounds (PUBG), and Valorant.

To ensure unbiased allocation and baseline comparability, the participants were stratified and randomly assigned into two equal cohorts using a simple random lottery drawing method:

1. Experimental Group (MBBW, n = 15**):** Completed the 5-minute Modified Brain Break Warm-up program prior to cognitive testing.
2. Control Group (General Warm-up, n = 15**):** Completed a standard warm-up routine prior to cognitive testing.

The demographic breakdown and primary gaming profiles of the participants are presented in Table 1.

Table 1. Demographic characteristics and primary gaming profiles of the participants.

Group	Players (*n*)	Male (*n*)	Female (*n*)	Primary Games
Experimental Group (MBBW)	15	9	6	ROV, PUBG, Valorant
Control Group (General Warm-up)	15	9	6	

Note. N = 30. This demographic distribution confirms that the participant pool was divided equally into two distinct groups to establish a balanced baseline framework for subsequent comparative analyses. This balanced layout ensures a valid comparison of the primary treatment condition (MBBW) against the control condition within identical skill and gender distributions.

Procedure

Instruments

1. The modified brain breaks warm-up program mapping matrix

To systematically evaluate and standardize the physical intervention, a Modified Brain Break Warm-Up Program Mapping Matrix was developed as a structural research instrument. The primary purpose of this instrument was to ensure content validity and cryptographic alignment between the theoretical ergonomics of E-sports and the practical 48-movement curriculum.

The instrument categorized the 48 total movements into a multi-dimensional matrix grid crossing the four thematic sets (Set 1: Mobility, set 2: Strength/Stretch, set 3: Coordination, and Set 4: Full Range) against three primary anatomical strain zones: (1) Upper Extremities and Ergonomic Strain Zones, (2) Core and Axial Skeleton Stability, and (3) Lower Extremities and Circulatory Support.

The Modified Brain Break Warm-up (MBBW) program was developed using a Research and Development (R&D) approach, structurally mapped into a 48-movement comprehensive curriculum. To prevent repetitive monotony and maintain high long-term engagement among players, these movements are organized into four distinct thematic sets (Set 1: Mobility, Set 2: Strength/Stretch, Set 3: Coordination, and Set 4: Full Range). Crucially, for the acute testing protocol in the present study, the intervention was standardized as a single 5-minute session. Participants were required to execute only one selected set containing 12 ergonomically tailored movements per testing session. The precise timeframe and pacing blueprint for the 5-minute (300 - second) protocol are operationalized as follows:

- Total Execution Time (240 seconds): Each of the 12 movements within the assigned set is strictly performed for a duration of 20 seconds (or 20 repetitions paced to the synchronized moderate-tempo background music of 100–105 BPM).

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- Total Transition Time (60 seconds): A standardized 5-second buffer is systematically allocated between consecutive movements to allow smooth postural transitions and ergonomic re-alignment without creating physical rushing or hyper-arousal.
- The final phase incorporates deep breathing for recovery after the warm-up.

A comprehensive step-by-step implementation guide detailing the 12 movements, biomechanical instructions, duration, and anatomical target areas is provided in Supplementary File 1 to facilitate research replication and practical implementation.

Table 2. Anatomical target and movement frequency across the four thematic sets.

Target muscle groups / Anatomical regions	**Set 1: Mobility**	**Set 2: Strength/Stretch**	**Set 3: Coordination**	**Set 4: Full range**	**Total Movement**
Upper extremities & ergonomic strain zones					
Cervical spine & neck (upper trapezius, sternocleidomastoid)	1	1	1	1	4
Shoulders & scapular (deltoids, rotator cuff, rhomboids)	2	2	3	2	9
Forearms, wrists, & fingers (flexors/extensors, lumbricals)	4	2	3	3	12
Core & axial skeleton stability					
Thoracic & lumbar spine (erector spinae, latissimus dorsi)	1	1	0	1	3
Abdominals & obliques (rectus abdominis, core stabilizers)	0	1	1	0	2
lower extremities & circulatory support					
Hip joint & pelvic girdle (gluteal, hip flexors/abductors)	1	1	1	2	5
Knees & thighs (quadriceps, hamstrings)	1	1	1	1	4
Ankles, feet, & calves (gastrocnemius, tibialis anterior)	2	2	2	1	7
Total frequency per set	**12**	**12**	**12**	**12**	**48**

Note. This matrix map functions as a structural validation instrument used to quantify and monitor the anatomical distribution of the 48 movements. It ensures that the physical workload is ergonomically optimized to mitigate physical fatigue and repetitive strain injuries in sedentary populations.

As presented in Table 2, the instrument quantitatively tracked the frequency of target movements to guarantee that the protocol focused heavily on high-risk gaming injury areas, specifically allocating 12 movements to the forearms, wrists, and fingers, and 16 movements to lower body circulation.

To establish the instrument's validity, the matrix and the corresponding movement guidelines were evaluated by a panel of three specialists in Exercise Physiology, E-sport Coaching, and Rhythmic Activities. The final instrument achieved an Item-Objective Congruence (IOC) score of 1.00, confirming perfect consensus regarding its biomechanical safety, structural alignment, and ergonomic relevance.

2. The Thai Athlete Mood Scale by Siripatt (2007)

The TAMS is a 24-item questionnaire designed to assess six core mood states in the immediate present that indicate how you feel right now, based on your feelings over the past few days, including: Anger, Confusion, Depression, Fatigue, Tension, and Vigor. Moreover, 5 Likert scale Not at all (0), A little (1), Moderately (2), Quite a bit (3), and Extremely (4).

3. Measuring Executive Function test.

The executive function component of the protocol was measured using three established neuropsychological tools, each targeting a distinct cognitive domain critical for high-level e-sport performance. The following list outlines the four specific tests used to measure key domains of executive function and reaction:

A. Shifting Between Tasks:
   - Cognitive Component: Cognitive Flexibility (Set Shifting)
   - Measurement Tool: Intra-Extra Dimensional Set Shift Test (IED) (Cambridge Cognition Ltd)
   - Description: A computerized task that measures the ability to shift attention between different visual stimuli rules (extradimensional shift) and is highly sensitive to frontal lobe function.

B. Inhibition of Dominant Responses:
   - Cognitive Component: Inhibitory Control
   - Measurement Tool: Stop Signal Task (SST) (Cambridge Cognition Ltd)
   - Description: A computerized test that measures the ability to inhibit a motor response that has already been initiated, providing a measure of response suppression latency (SSRT).

C. Updating of Working-Memory:
   - Cognitive Component: Working Memory (Spatial Component)
   - Measurement Tool: Spatial Working-memory Test (SWM) (Cambridge Cognition Ltd)
   - Description: A computerized test of spatial memory and executive function that requires participants to search for tokens in boxes, remembering where tokens have already been found.

D. Reaction:
   - Cognitive Component: Speed of Processing / Interference Control
   - Measurement Tool: Colour Word Stroop Test (Stroop, 1935)
   - Description: A classical test of interference, measuring the time difference (interference score) between reading congruent vs. incongruent colour-word stimuli (e.g., the word "BLUE" printed in red ink).

E. Refocusing Ability:
   - Cognitive Component: Refocusing Ability
   - Measurement Tool: Thai version of the Sports Mindfulness Test (Singnoy et al., 2020).
   - Description: Tested using 6 refocus items from this scale, which is a six-level valuation questionnaire, to measure an individual's capacity to bring their attention back to the present moment.

All cognitive outcome measures were delivered via automated, computerized testing scripts utilizing non-verbal visual stimuli to prevent linguistic bias. Mood states were assessed using the validated Thai version of the Profile of Mood States (POMS-Short Form; internal consistency in the present study: Cronbach's alpha = .81- .89). Attentional refocusing was operationalized using the 6-item Refocusing Subscale of the Thai Sport Mindfulness Inventory (TSMI), previously validated in collegiate athletic populations (Cronbach's alpha = .84). Confirmatory factor loading for these six items ranges between 0.72 and 0.86, confirming the structural validity of isolating this acute post-performance refocusing facet.

Data collection procedure

The experimental protocol was conducted in a strictly controlled laboratory environment with standardized ambient lighting, temperature (24–25°C), and acoustic conditions to minimize extraneous interference. A randomized controlled trial (RCT) design with repeated measures across distinct time points was implemented through the following standardized phases (Figure 1).

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1. Baseline Assessment (T_0 – Pre-intervention):
   Prior to any physical or gaming activity, all participants in both cohorts underwent an individual baseline cognitive and psychological assessment. This battery included the executive function tasks (Intra-Extra Dimensional Set Shift [IED], Stop Signal Task [SST], Spatial Working Memory [SWM], and the Colour-Word Stroop Test) and the transient mood assessment using the Thai Athlete Mood Scale (TAMS). Additionally, baseline attentional refocusing ability was recorded using the refocus subscale of the Thai version of the Sports Mindfulness Test.

2. Intervention Phase (5 Minutes):
   Immediately following the baseline evaluation, participants executed their assigned 5-minute pre-match preparatory condition:
   - Experimental Group (MBBW): While the overarching MBBW framework includes a 48-movement repository designed for multi-week curriculum integration, the present acute trial utilized a single, standardized 12-movement protocol administered identically to all MBBW participants. The 5-minute acute protocol comprised a standardized single set of 12 ergonomically tailored movements (totalling 240 seconds of execution and 60 seconds of transitional buffer), paced via video demonstration.
   - Control Group (Habitual Gaming Routine): To avoid ambiguity, the comparator group was designated exclusively as the Habitual Seated Control (HSC) condition. Participants in the HSC group remained seated in standardized gaming chairs for an identical 5-minute period under researcher observation. During this interval, participants were permitted to engage in non-strenuous pre-match habitual behaviours typical of collegiate gaming (e.g., peripheral hardware adjustments, in-game client/lobby navigation, passive seating posture adjustments). They did not perform physical warm-ups, stretching, or active gameplay. This design isolated the acute physical and coordinal activation of MBBW while holding seated environment and anticipation constant.

3. Immediate Post-Intervention Assessment (T_1 – Acute Effect):
   To evaluate the direct acute neurocognitive and affective shifts induced by the 5-minute interventions, participants were immediately reassessed within 3 minutes post-intervention. This test battery mirrored the baseline evaluation, measuring executive functions (inhibitory control, task switching, working memory, Stroop reaction times) and transient mood states (TAMS).

4. Standardized E-sports Competitive Session:
   Following the T_1 assessment, all participants from both groups engaged in an intensive, standardized 60-minute competitive E-sports gameplay session in their designated titles (ROV, PUBG, or Valorant) under simulated tournament conditions to elicit natural competitive cognitive load and mental fatigue.

5. Post-Gaming Attentional Refocusing Assessment (T_2):
   Immediately upon concluding the competitive match session, participants were assessed on their Attentional Refocusing Ability using the Sports Mindfulness Test refocus subscale. This final time-point was specifically implemented to determine whether the acute pre-game kinetic break provided sustained cognitive scaffolding, enabling players to effectively regain focus and recover attentional resources.

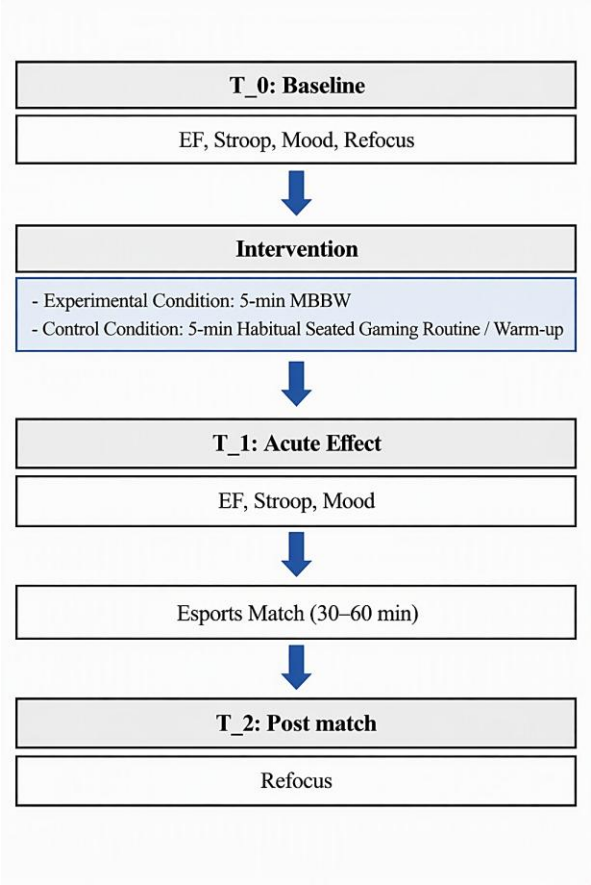


Figure 1. Schematic experimental timeline.

Data analysis

Distributional normality was verified through Shapiro-Wilk testing and visual Q-Q plot inspection. For normally distributed variables meeting the assumption of homogeneous regression slopes ($p > .05$ for Group x times Baseline), Analysis of Covariance (ANCOVA) was executed, specifying baseline values as the covariate and post-test values as the dependent variable. Where severe distributional skewness violated parametric assumptions (specifically the Anger and Depression subscales of the POMS), between-group differences were evaluated using Mann-Whitney *U* tests on change scores (Delta = Post - Pre), with rank-biserial correlations (*r*) reported as non-parametric effect sizes. Prior to inferential analyses, data normality was systematically assessed using the Shapiro-Wilk test. For neurocognitive and mood dimensions that satisfied parametric assumptions, a One-way Analysis of Covariance (ANCOVA) or standard ANOVA was executed, using baseline scores as covariates where applicable. Pairwise post-hoc comparisons were subsequently adjusted using Scheffé, Games-Howell, or Tukey HSD methods based on the homogeneity of variance verified by Levene's test. Conversely, for variables demonstrating significant deviations from normal distribution ($p < .05$), a non-parametric approach via the Kruskal-Wallis *H* test was employed, followed by the Dwass-Steel-Critchlow-Fligner (DSCF) method for rigorous post-hoc pairwise comparisons. To control for Type I error inflation arising from multiple hypothesis testing across cognitive and affective batteries, the Benjamini-Hochberg False Discovery Rate (FDR) procedure was applied within predefined outcome families: (1) Executive Function and Psychomotor Performance, and (2) Mood State Dimensions. Both unadjusted two-tailed *p*-values and multiplicity-adjusted *q*-values (*p*FDR) are reported. Statistical significance was evaluated at $p\text{FDR} < .05$.

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RESULTS

The following analyses evaluate the acute preliminary effects of the MBBW program compared to the habitual seated control condition on cognitive readiness domains and transient mood states.

Effects on executive functions and refocusing ability

Table 3. Acute effects of the modified brain break warm-up (MBBW) on executive functions and refocusing ability.

Cognitive Domain/ Variable	Experimental Group (n = 15)	Control Group (n = 15)	Statistical Model	p-value	Effect Size (Cohen's d)
Parametric Variables (ANCOVA, F)					
Short-Term Memory					
Pre-Test (Score)	11.79 ± 2.65	13.04 ± 1.33	F = 16.97	.001**	Medium-Large
Post-Test (Score)	13.92 ± 1.72	12.96 ± 1.43			
Working Memory Updating					
Pre-Test (Score)	6.17 ± 2.96	6.54 ± 2.25	F = 28.22	<.001**	0.86 (Large)
Post-Test (Score)	8.21 ± 2.92	5.96 ± 2.26			
Refocusing Ability (Measured at T_2)					
Pre-Test (Score)	4.03 ± 0.72	4.01 ± 0.42	F = 34.76	<.001**	1.16 (Large)
Post-Test (Score)	4.60 ± 0.77	3.89 ± 0.38			
Non-Parametric Variables (Kruskal-Wallis, H)					
Inhibitory Control					
Pre-Test (ms)	255.0 ± 93.5	228.7 ± 53.9	H = 5.33	.021*	0.15 (Small)
Post-Test (ms)	217.3 ± 100.2	230.2 ± 64.2			
Processing Speed & Attention					
Pre-Test (s)	24.52 ± 8.62	21.07 ± 2.00	H = 34.78	.001**	Large
Post-Test (s)	16.94 ± 4.98	21.22 ± 1.42			
Task Shifting (Cognitive Flexibility)					
Pre-Test (s)	56.22 ± 23.40	46.18 ± 8.13	H = 29.41	<.001**	0.82 (Large)
Post-Test (s)	35.25 ± 17.62	46.07 ± 6.57			

Note. Values are expressed as Mean ± Standard Deviation ($M \pm SD$). F-statistics denote One-Way ANCOVA models with baseline (T_0) scores entered as covariates. H-statistics represent non-parametric Kruskal-Wallis analyses evaluated on baseline-to-post change scores (Delta) due to deviations from normality assumptions. Executive functions and processing speed were reassessed immediately post-warm-up (T_1), whereas Attentional Refocusing Ability was evaluated following the standardized competitive match session (T_2). *$p < .05$, *$p \leq .001$.

The comparative analysis of the acute effects of the 5-minute Modified Brain Break Warm-up (MBBW) program against the habitual gaming control routine across executive function domains and attentional refocusing ability is summarized in Table 3.

For normally distributed neurocognitive parameters evaluated via parametric models, the One-Way Analysis of Covariance (ANCOVA)—utilizing baseline (T_0) scores as covariates—demonstrated statistically significant post-intervention superiorities in the experimental group. Specifically, participants undergoing the MBBW program exhibited significantly greater enhancement in Working Memory Updating at T_1 compared to the control cohort (F = 28.22, p < .001), accompanied by a large effect size (d = 0.86). Similarly, a statistically significant acute improvement was observed in Short-Term Memory capacity (F = 16.97, p = .001, medium-to-large effect). Crucially, for Attentional Refocusing Ability assessed post-match (T_2), the experimental group demonstrated a profound capacity to regain attentional focus following competitive cognitive exertion compared to the control condition (F = 34.76, p < .001), yielding the most substantial positive magnitude of effect across all measured domains (d = 1.16).

For cognitive variables exhibiting non-normal distributions (evaluated through the Kruskal-Wallis *H* test on change scores from baseline), the MBBW intervention elicited statistically significant improvements across all assessed domains. The experimental group showed a significant reduction in response suppression latency in Inhibitory Control ($H = 5.33$, $p = .021$, $d = 0.15$). Furthermore, processing speed and sustained visual attention improved substantially in the MBBW group ($H = 34.78$, $p = .001$, large effect). Most notably, Cognitive Flexibility (Task Shifting latency) showed a marked post-intervention optimization, with the experimental group completing shift stages significantly faster than the control group ($H = 29.41$, $p < .001$, $d = 0.82$).

Collectively, these findings confirm that a targeted 5-minute kinetic break selectively primes and up-regulates prefrontal-dependent executive functions immediately prior to performance (T_1), while providing a sustained cognitive buffer that enhances attentional refocusing following prolonged competitive gameplay (T_2).

Table 4. Comparison of Reaction Time Performance (Stroop Test).

Condition / Variable	Experimental Group (n = 15)	Control Group (n = 15)	Z-score	p-value	Effect Size (Cohen's d)
Incongruent RT (ms)	414.9 ± 107.3	464.3 ± 70.9	−4.11	.004**	0.54 (Medium)
Congruent RT (ms)	197.7 ± 43.1	234.0 ± 38.1	−1.79	.205	0.89 (Large)

Note: Values are expressed as Mean ± Standard Deviation ($M \pm SD$). F-statistics denote One-Way ANCOVA models with baseline (T_0) scores entered as covariates. H-statistics represent non-parametric Kruskal-Wallis analyses evaluated on baseline-to-post change scores (Delta) due to deviations from normality assumptions. Executive functions and processing speed were reassessed immediately post-warm-up (T_1), whereas Attentional Refocusing Ability was evaluated following the standardized competitive match session (T_2). *$p < .05$, **$p \leq .001$.

Table 4 illustrates the post-intervention comparative analysis of reaction time (RT) performance under both demanding and basic processing conditions of the Stroop Test. For the highly demanding Incongruent RT condition, the non-parametric pairwise comparison demonstrated that the experimental group achieved a statistically significantly faster reaction time compared to the control group ($Z = -4.11$, $p = .004$), yielding a medium standardized effect size ($d = 0.54$). Conversely, for the Congruent RT condition, the analysis revealed no statistically significant difference between the two groups ($p = .205$). Although the experimental group exhibited a nominally lower mean latency (197.7 ± 43.1 ms) compared to the control group (234.0 ± 38.1 ms), this variance failed to reach the required statistical threshold (calculated $d = 0.89$). This statistical divergence suggests that the acute neural benefits of the 5-minute MBBW protocol are highly selective, specifically optimizing computational conflict resolution and interference control networks rather than merely accelerating basic, low-demand motor outputs.

Table 5. Changes in Mood States (TAMS) After Warm-up.

Mood Dimension	Experimental Group (n = 15)	Control Group (n = 15)	Statistical Model	p-value	Effect Size (Cohen's d)
Depression	1.73 ± 0.72	1.97 ± 0.32	F=19.37	<.001**	0.43 (Medium)
Fatigue	2.03 ± 0.66	2.56 ± 0.52	F=41.23	<.001**	0.89 (Large)
Confusion	1.96 ± 0.72	1.91 ± 0.15	H=27.42	<.001**	0.10 (Small)
Anger	1.70 ± 0.72	1.74 ± 0.24	H=23.24	<.001**	0.07 (Small)
Vigor	3.68 ± 0.73	3.30 ± 0.26	H=2.96	.085	0.69 (Medium)

The post-intervention analysis of transient affective states measured by the Thai Athlete Mood Scale (TAMS) is summarized in Table 5. For emotional dimensions that met parametric criteria, standard One-Way ANOVA models demonstrated that the experimental group scored significantly lower levels of negative affect compared to the control group in both Depression ($F = 19.37$, $p < .001$, $d = 0.43$) and Fatigue ($F = 41.23$, $p < .001$, $d = 0.89$, Large Effect). Regarding dimensions analysed via non-parametric approaches, the Kruskal-

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Wallis *H* test revealed highly significant post-intervention reductions in the experimental group for Confusion ($H = 27.42$, $p < .001$, $d = 0.10$) and Anger ($H = 23.24$, $p < .001$, $d = 0.07$). However, for the positive affect dimension of Vigor, the difference between the experimental (3.68 ± 0.73) and control (3.30 ± 0.26) groups did not reach statistical significance ($H = 2.96$, $p = .085$), despite exhibiting a nominal moderate effect size ($d = 0.69$). These results collectively demonstrate that the 5-minute MBBW intervention is highly effective in down-regulating psychological distress and subjective fatigue, thereby fostering a more optimal, baseline-stabilized emotional profile prior to competitive execution.

DISCUSSION AND CONCLUSIONS

The primary objectives of this preliminary exploratory proof-of-concept study ($N = 30$) were to evaluate the feasibility of a tailored Modified Brain Break Warm-up (MBBW) program and investigate its acute, exploratory effects on executive functions (task shifting, working memory, and inhibitory control), attentional refocusing ability, and transient mood states in collegiate esports players. Our preliminary findings provide encouraging initial evidence that a brief, 5-minute ergonomically aligned kinetic routine can acutely prime cognitive readiness and down-regulate negative mood states prior to competition

Cognitive Scaffolding, Executive Functions, and the "Brain Break" Phenomenon

The post-intervention results revealed substantial improvements in the experimental group's executive functions—specifically in task shifting ($d = 0.82$) and working memory ($d = 0.86$)—alongside an exceptionally large effect size in attentional refocusing ($d = 1.16$, $p < .001$). These acute enhancements align with the broader consensus in exercise psychology that short, structured bouts of physical activity stimulate neural mechanisms necessary for immediate cognitive enhancement (Brisswalter et al., 2002; Tomporowski, 2003; Tomporowski & Ellis, 1986). The significant post-intervention improvements observed in task shifting, working memory, and attentional refocusing provide preliminary evidence supporting the utility of the MBBW program as a structured pre-performance cognitive priming routine tailored for mentally demanding gaming environments. In collegiate esports, competitors operate within complex cognitive settings requiring continuous executive control under pressure. Our findings suggest that this brief 5-minute movement routine disrupted cumulative cognitive resource depletion, facilitating acute conflict resolution (evidenced by decreased Stroop Incongruent reaction times) and subjective fatigue reduction.

However, it is crucial to explicitly emphasize that the present findings reflect acute optimizations in foundational cognitive and emotional substrates—specifically attentional flexibility, working memory updating, and affective stability—rather than direct, verified enhancements in competitive gaming success. While these executive functions serve as indispensable prerequisites for high-level esports performance, the current trial did not capture telemetry-based match metrics, in-game tactical decision-making, actions per minute (APM), or kill/death/assist (KDA) outcomes. Consequently, these results must be interpreted strictly as an exploratory proof-of-concept demonstrating pre-match cognitive and psychological readiness, whereas the direct ecological transfer of these cognitive gains to competitive match execution remains an empirical question to be validated in future research. Although neuroimaging and autonomic biomarkers were not directly measured in the present trial, the acute cognitive and affective adjustments observed may theoretically align with mechanisms documented in broader exercise science literature. Prior investigations suggest that brief, coordinated movement bouts can transiently elevate prefrontal cortical blood flow and downregulate mental fatigue networks. However, these physiological pathways remain speculative within the scope of our behavioural data and warrant direct empirical testing via neuroimaging modalities (e.g., fNIRS or EEG) in future e-sports trials.

Crucially, the massive improvement in refocusing ability and task shifting can be structurally interpreted through Attention Restoration Theory (ART). Competitive gaming places severe, prolonged demands on players' "directed attention" capacities, leading to cognitive fatigue (Lopes de Lima et al., 2025). Shifting an athlete's focus away from a high-cognitive-load digital screen to a series of physical movements acts as a restorative stimulus. This phenomenon has been profoundly validated by Yu et al. (2025), who utilized advanced neuroimaging to demonstrate that physical exercise breaks significantly modulate and restore neural activity associated with central executive control in simulated classroom environments. Indeed, introducing short kinetic pauses during mentally demanding operations resets attentional networks, prevents off-task behaviour, and optimizes subsequent focus (Blasche et al., 2018; Ferrer & Laughlin, 2017; Godwin et al., 2016; Paulus et al., 2021; Rice, 2023).

From a brain-based learning perspective, movement is an indispensable scaffolding tool for cognitive functioning (Caine & Caine, 1991; Jensen, 2005, 2008; Lengel & Kuczala, 2010). Within this specialized framework, the MBBW program serves as an organic "biomechanical and cognitive scaffolding". It unburdens the active working memory by temporarily transitioning the athlete from complex digital problem-solving to predictable physical motor patterns. Under intense competitive E-sports matches, the accumulated stress induces psychological anxiety and cognitive "blocking," creating severe emotional barriers that temporarily restrict motor execution and executive output. Introducing a structured, low-stakes kinaesthetic break protocol provides a safe, restorative window that alleviates this neural bottleneck, diminishes competitive cognitive fatigue, and reinstates self-efficacy prior to subsequent gameplay. Indeed, introducing short kinetic pauses or micro-breaks during mentally demanding operations has been robustly validated through meta-analytic evidence to reset attentional networks, alleviate cognitive fatigue, and optimize subsequent performance (Albulescu et al., 2022).

The classification of MBBW as closed-skill exercise describes its predictable motor demands; it does not establish superiority over open-skill exercise or other active interventions. The cognitive superiority of our developed protocol is further illuminated by its classification as a "closed-skill exercise". Performing structured, predetermined movements within a stable, predictable environment yields significantly higher cognitive restoration benefits than open-skill tasks, as it minimizes the need for real-time external decision-making and environmental processing (Gu et al., 2019). While professional and amateur action video game players inherently exhibit robust baseline visual working memory, superior spatial attention distribution, and lower task-switching costs due to prolonged training (Blacker & Curby, 2013; Blacker et al., 2014; Cain et al., 2012; Green & Bavelier, 2003, 2006), intense game execution eventually induces a bottleneck effect under competitive stress. The MBBW program successfully mitigates this cognitive resource depletion, effectively "re-opening" the executive control network, a finding that mirrors the acute executive improvements documented by Chang et al. (2011) and McMorris and Graydon (2000).

Mechanisms of Conflict Resolution and Interference Control

Regarding interference control, the Stroop Test results showed that the experimental group achieved significantly faster reaction times in the Incongruent RT condition (p = .004, d = 0.54), though the overall effect size for baseline inhibitory control was relatively small (d = 0.15). This discrepancy suggests that while a 5-minute warm-up may not drastically alter fundamental motor inhibition (which is already highly developed in gamers; see Chisholm et al., 2010), it is highly effective in upgrading cognitive systems responsible for resolving computational conflicts and managing high-interference environments.

This result provides an essential countermeasure to mental fatigue, which typically deteriorates an athlete's technical precision and behavioural inhibition under prolonged cognitive demands. Competitive gaming

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places severe, prolonged demands on players' 'directed attention' capacities, leading to mental fatigue, which has been systematically proven to impair skilled performance and cognitive execution in athletic contexts (Sun et al., 2021). Interventions that target physical-cognitive synergy, such as "Brain Gym" or kinaesthetic coordination activities, have been shown to facilitate hemispheric integration and improve coordination tasks (Dennison & Dennison, 1997; Maskell et al., 2004). By deploying structured bilateral coordination movements (e.g., knee-to-chest, arm swings, wrist supination/pronation) under the rhythmic guidance of music, the MBBW program recruits both cerebral hemispheres, facilitating rapid neural transmission and motor-sensory integration (Lengel & Kuczala, 2010; Stevens-Smith, 2016). Consequently, when gamers return to their workstations, the prefrontal infrastructure is refreshed, allowing the brain to successfully navigate high-interference cognitive streams and suppress irrelevant visual distractors during gameplay (Gong et al., 2019; Green & Bavelier, 2003).

Neuro-Affective Regulation, Mood States, and Ergonomics

Beyond cognitive readiness, the intervention yielded statistically significant acute reductions across negative affective dimensions, notably depression, anger, confusion, and subjective fatigue ($p < .001$). From a mechanistic standpoint, while prior cognitive neuroscience literature indicates that brief physical activity can modulate neural arousal, promote prefrontal cortical hemodynamic, and influence attentional allocation networks, the present investigation did not directly collect neuroimaging (e.g., fNIRS, fMRI) or electrophysiological (e.g., EEG, autonomic HRV) data. Accordingly, potential neural mechanisms—such as the restoration of attentional networks, autonomic parasympathetic shifts, or the theoretical modulation of resting-state networks like the Default Mode Network (Thomson et al., 2015)—must be framed strictly as literature-derived hypotheses rather than empirically verified adaptations.

Rather than demonstrating direct neurophysiological remodelling, our behavioural and psychological findings correspond with observations by Sudo and Ando (2020), who demonstrated that acute bouts of structured kinetic movement and stretching effectively attenuate perceived psychological tension and somatic distress in physically inactive cohorts. Interrupting high-demand screen engagement with structured physical movement likely provides an acute psychological respite and sensory reset, thereby fostering an emotionally stabilized baseline prior to competition without inducing hyper-arousal.

Furthermore, the profound reduction in subjective fatigue ($p < .001$, $d = 0.89$) stands as a cornerstone of this intervention's efficacy. E-sports players suffer from severe static loading and physical stress concentrated in highly repetitive musculoskeletal zones, including the cervical spine, shoulders, lumbar region, and distal upper extremities (DiFrancisco-Donoghue et al., 2019; Hwu, 2018). This prolonged static posture causes localized ischemia, muscle tightness, and discomfort, which inevitably increases perceived physical fatigue and degrades mental focus (Kendal et al., 2022).

Our modified program directly addresses this ergonomic crisis. By introducing a tailored 48-movement curriculum that targets specific physical vulnerabilities—such as wrist flexion/extension, scapular squeezing, and hip mobility (as mapped in Table 1 and Table 2)—the MBBW program physically disrupts sedentary fatigue. Keating et al. (2022) and Lynch et al. (2022), who concluded that active, structured breaks of short duration diminish somatic discomfort and fatigue in sedentary computer users and university students. By improving local blood circulation and breaking up joint stiffness, physical movement stimulates somatic receptors, sending positive feedback to the central nervous system, which in turn reduces the subjective feeling of exhaustion (Kuczala, 2015; Peiris et al., 2021; Reilly et al., 2012).

Acoustic-Motor Alignment and the Paradox of Vigor

Conversely, the lack of a statistically significant change in "Vigor" (p = .085) warrants critical academic discussion. In sports and exercise psychology, vigour is highly dependent on autonomic arousal, which is directly modulated by the acoustic properties and tempo of accompanying music (Karageorghis et al., 2006; Priest et al., 2004). In this study, audio tracks were intentionally anchored at a moderate tempo of 100–105 BPM to foster a unique state of "calm alertness" (Jensen, 2001; Kuan et al., 2019). While a rapid, highly motivational musical tempo (>120 BPM) may be required to dramatically spike subjective vigour and physical excitement (Barney et al., 2021), it simultaneously runs the risk of elevating physiological anxiety or inducing pre-match jitters.

Because high-level E-sports execution demands extreme fine-motor precision, microsecond reaction times, emotional stability, and strategic clarity, a deliberate state of calm alertness—rather than hyper-arousal—is biomechanically and psychologically preferred. Hyper-arousal can lead to muscle tremors, poor coordination, and cognitive rushing, which are detrimental to professional gaming performance. Therefore, maintaining steady vigour while successfully minimizing negative emotions and anxiety confirms that the acoustic-motor parameters of our MBBW program functioned exactly as ergonomically intended. It establishes a physiological baseline of readiness without pushing the athlete into a state of hyper-aroused cognitive instability.

By integrating exercise physiology with cognitive psychology, the MBBW program transcends traditional gaming warm-ups. Crucially, from a pedagogical perspective, this 5-minute closed-skill kinetic routine provides universities and physical educators with a standardized, evidence-based health intervention. It can be seamlessly implemented as an "active classroom break" to combat the widespread sedentary behaviour and mental fatigue observed in modern digital learning environments, ultimately fostering both physical well-being and cognitive resilience in collegiate populations.

Practical & Public Health Implications

Beyond its specialized utility within competitive gaming environments, the architectural design of the Modified Brain Break Warm-up (MBBW) offers substantial translational relevance for broader public health and educational domains. The physical and cognitive patterns observed in competitive esports—specifically prolonged, uninterrupted static sitting, continuous visual fixation on digital displays, and chronic cognitive loading—are virtually identical to the ergonomic challenges faced by modern university students, distance learners, and desk-based knowledge workers. Prolonged sedentary behaviour has been extensively documented to induce musculoskeletal discomfort, localized muscular ischemia in the cervicothoracic region, and progressive depletion of directed attention resources, which collectively precipitate physical stagnation and mental fatigue. From a practical implementation standpoint, the MBBW protocol presents a highly viable, scalable, and low-barrier micro-break intervention suitable for everyday sedentary environments. Because the 5-minute routine requires minimal physical footprint, zero specialized exercise equipment, and no attire modifications, it can be seamlessly embedded into university lecture halls, online learning platforms, and corporate office workstations. Integrating brief, structured closed-skill kinetic breaks into academic or work schedules can systematically interrupt sedentary screen time, enhance peripheral circulation, and mitigate upper-extremity postural strain. Furthermore, by promoting acute executive restoration and down-regulating transient negative affect (such as subjective fatigue and tension), this structured physical break serves as an effective pedagogical and occupational health tool. Implementing such movement-based micro-interventions at institutional levels could foster physical well-being, optimize cognitive readiness for continuous learning tasks, and provide an evidence-based physical activity strategy to combat the pervasive health risks associated with sedentary screen-centric lifestyles.

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Limitations and Future Directions

Although the present investigation provides encouraging preliminary evidence supporting the utility of a brief kinetic break for pre-competitive cognitive priming, several methodological constraints must be transparently addressed to contextualize the findings and guide future research:

Sample Scope and Generalizability

The study was conducted with a modest sample size (N = 30) drawn from a single university population. While adequate for an exploratory proof-of-concept trial and preliminary variance estimation, this limited cohort restricts statistical power and limits external validity. Consequently, the effect-size estimates should be interpreted as preliminary benchmarks. Future research requires multi-centre replication trials incorporating substantially larger, culturally diverse cohorts to establish definitive efficacy.

Ecological Validity and In-Game Performance Metrics

A central delimitation of this study is that performance was assessed exclusively via laboratory neuropsychological batteries (e.g., Stroop, IED, SWM) and self-report affective scales rather than direct esports-performance outcomes. While these cognitive tests reflect critical foundational substrates for competitive gaming, the protocol did not record telemetry-based in-game performance metrics, such as actions per minute (APM), hit accuracy, tactical decision-making latency, kill/death/assist (KDA) ratios, or objective match outcomes. Future studies should integrate in-game telemetry tracking and simulated match analytics to verify the ecological transfer of acute cognitive priming to competitive match success.

Intervention Duration and Adaptation Trajectory

The current protocol evaluated only the acute, immediate effects of a single 5-minute warm-up session. It remains undetermined whether these transient cognitive and affective benefits persist throughout prolonged tournament schedules or yield cumulative adaptations. Future research should implement longitudinal intervention designs across multi-week training camps or entire competitive seasons to examine chronic neurocognitive adaptations, habituation effects, and the potential mitigation of competitive burnout and repetitive strain injuries.

Comparator Condition and Active Exercise Controls

The experimental protocol was evaluated against a habitual seated resting control condition, which reflects standard sedentary pre-match behaviours in esports. However, the absence of an active exercise comparator (e.g., brisk walking, stationary cycling, or general non-targeted stretching) precludes isolating whether the observed cognitive gains stemmed specifically from the tailored, closed-skill choreographic design of the MBBW or were merely the general result of non-specific light physical arousal. Subsequent trials should incorporate active control arms to confirm protocol-specific mechanistic advantages.

Direct Physiological and Neurobiological Verification

The proposed mechanistic pathways underlying the observed cognitive enhancements—such as Default Mode Network recovery, prefrontal hemodynamic, and autonomic nervous system regulation—remain speculative and theoretical within this study, as no direct physiological markers were gathered. To substantiate these proposed neurophysiological mechanisms, future investigations must incorporate objective physiological and neuroimaging modalities, such as functional near-infrared spectroscopy (fNIRS), electroencephalography (EEG), and continuous heart rate variability (HRV) monitoring.

Genre and Competitive Tier Stratification

The participant pool comprised collegiate amateur players competing across varied game titles (e.g., MOBA and tactical FPS). The modest sample size precluded stratified subgroup analyses to determine whether

cognitive benefits interact with specific genre mechanics (such as the visual-spatial tracking demands of FPS vs. the multi-agent tactical planning of MOBA). Moreover, elite professional esports athletes exhibit distinct baseline cognitive architectures and stress coping mechanisms compared to collegiate players. Future research should systematically examine the protocol's efficacy across distinct esports genres and stratified competitive tiers (amateur, collegiate, semi-professional, and elite professional divisions).

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows:

Conceptualisation: Pongsatorn Sritubtim, Chatkamon Singnoy, Tanida Julavanichpong, Garry Kuan. Methodology: Pongsatorn Sritubtim, Chatkamon Singnoy, Tanida Julavanichpong, Garry Kuan, Poonpong Suksawang. Formal analysis: Pongsatorn Sritubtim, Poonpong Suksawang. Investigation: Pongsatorn Sritubtim. Data curation: Pongsatorn Sritubtim, Poonpong Suksawang. Writing – original draft: Pongsatorn Sritubtim, Chatkamon Singnoy. Writing – review & editing: Chatkamon Singnoy, Tanida Julavanichpong, Garry Kuan, Poonpong Suksawang, Yu-Kai Chang. Supervision: Chatkamon Singnoy, Tanida Julavanichpong, Garry Kuan, Yu-Kai Chang.

All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

ETHICAL APPROVAL AND INFORMED CONSENT

The study protocol was approved by the Human Research Ethics Committee of Burapha University, Thailand (approval reference number: G-HS034/2567(C1); approval date: 28 Aug 2025), in accordance with the Declaration of Helsinki prior to the recruitment and commencement of experimental procedures. Written informed consent was obtained from all participants before their participation in the study.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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ACKNOWLEDGEMENTS

The authors express their sincere gratitude to all the collegiate esports players from Chiang Mai Rajabhat University who voluntarily participated in this study. Their time, dedication, and active engagement throughout the experimental trials were fundamental to the completion of this research. The authors also wish to thank the university's esports club coordinators and department staff for their valuable logistical support and for facilitating the recruitment process.

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