Pressure, coping strategies, and psychological preparation in university sports competitions

Presión, estrategias de afrontamiento y preparación psicológica en competiciones deportivas universitarias

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Abstract

Introduction: University athletes experienced considerable psychological pressure due to the simultaneous demands of competitive sport and academic responsibilities, while systematic psychological preparation remained limited within collegiate sport programs.
Objectives: The study aimed to examine the multidimensional structure of competitive pressure, evaluate the effectiveness of a periodized psychological preparation intervention, and validate a composite psychological load monitoring index among university athletes.
Methods: A longitudinal quasi-experimental design was employed across two competitive seasons. The sample comprised 312 university athletes from twenty-eight sports disciplines. Repeated psychological, physiological, and performance-related measures were collected before, during, and after a sixteen-week multimodal psychological preparation program. Data were analyzed using confirmatory factor analysis and multilevel modeling to assess structural validity, intervention effects, and moderating individual factors.
Results: Confirmatory factor analysis supported a three-factor model of competitive pressure, demonstrating excellent fit (comparative fit index = 0.971; Tucker–Lewis index = 0.965; root mean square error of approximation = 0.048). The intervention produced significant improvements in autonomic regulation (β = 0.41), reductions in cognitive anxiety (β = −2.84), and enhanced competitive performance (β = 0.52). Physiological stress reactivity and recovery showed large effect size improvements (d = 1.02–1.53). Maladaptive perfectionism significantly moderated intervention responsiveness. The Psychological Load Index demonstrated high predictive accuracy for performance outcomes (area under the curve = 0.87).
Conclusions: The findings demonstrated that structured psychological preparation significantly improved psychological regulation, physiological stress control, and athletic performance. Multimodal monitoring provided superior predictive value compared to single-method assessment, supporting its integration into university sport systems.

Keywords

Competitive pressure; coping strategies; performance anxiety; psychological preparation.

Resumen

Introducción: Los atletas universitarios experimentaron una presión psicológica considerable debido a las exigencias simultáneas del deporte competitivo y las responsabilidades académicas, mientras que la preparación psicológica sistemática fue limitada dentro de los programas deportivos universitarios.
Objetivos: El estudio buscó examinar la estructura multidimensional de la presión competitiva, evaluar la efectividad de una intervención periodizada de preparación psicológica y validar un índice compuesto de monitoreo de la carga psicológica en atletas universitarios.
Métodos: Se empleó un diseño cuasiexperimental longitudinal a lo largo de dos temporadas competitivas. La muestra estuvo compuesta por 312 atletas universitarios de veintiocho disciplinas deportivas. Se recopilaron medidas psicológicas, fisiológicas y de rendimiento repetidas antes, durante y después de un programa multimodal de preparación psicológica de dieciséis semanas. Los datos se analizaron mediante análisis factorial confirmatorio y modelado multinivel para evaluar la validez estructural, los efectos de la intervención y los factores individuales moderadores. Resultados: El análisis factorial confirmatorio respaldó un modelo trifactorial de presión competitiva, demostrando un ajuste excelente (índice de ajuste comparativo = 0,971; índice de Tucker-Lewis = 0,965; error cuadrático medio de aproximación = 0,048). La intervención produjo mejoras significativas en la regulación autonómica (β = 0,41), reducciones en la ansiedad cognitiva (β = -2,84) y un mejor rendimiento competitivo (β = 0,52). La reactividad y la recuperación ante el estrés fisiológico mostraron mejoras significativas en el tamaño del efecto (d = 1,02-1,53). El perfeccionismo desadaptativo moderó significativamente la capacidad de respuesta a la intervención. El Índice de Carga Psicológica demostró una alta precisión predictiva para los resultados de rendimiento (área bajo la curva = 0,87).
Conclusiones: Los hallazgos demostraron que la preparación psicológica estructurada mejoró significativamente la regulación psicológica, el control del estrés fisiológico y el rendimiento deportivo. La monitorización multimodal proporcionó un valor predictivo superior en comparación con la evaluación de un solo método, lo que respaldó su integración en los sistemas deportivos universitarios.

Palabras clave

Presión competitiva; estrategias de afrontamiento; ansiedad por el rendimiento; preparación psicológica.

Introduction

University sports events are a multifaceted performance context where athletes must cope with the high-pressure competitive requirements and academic and social loads. In contrast to professional sportsmen, college athletes have to work in the field of dual-role expectations, which is a combination of athletic performance and academic success (Li et al., 2025), (Nogueira et al., 2025). This dual burden increases the psychological pressures, which tend to be in the form of increased competitive anxiety, emotional strain and lack of concentration during performance. According to empirical evidence, university athletes report more anxiety, stress symptoms than their non-athlete counterparts, and this is due to the compounding effect of the competition schedules, performance evaluation, and academic workload. These pressures do not only affect psychological well being but also affect the physiological stress regulation, such as imbalance of the autonomic nervous system and enhanced hormonal stress response before competition. Therefore, the sporting performance on the college level is more and more being acknowledged as the product of physical training and psychological preparedness (Kara & Ceyhan, 2025), (Cui et al., 2025), (Dos Santos et al., 2020).

Psychophysiological effects of prolonged competitive stress are huge. Increased anxiety is linked to disruption of attention, poor decision-making and poor motor performance especially during time-constrained sport situations. The pre-competition stress responses such as an increase in cortisol secretion and maladaptive cardiovascular responses can alter the athletes into threat-oriented responses instead of challenge-based responses thus compromising performance consistency). Such stress reactions are not universal in all athletes; personal factors like scholarship, experience in competition and personality also influence susceptibility to pressure. Consequently, athletes who develop continuous psychological pressure can alternately change the performance of academic functioning, slow the recovery process, and develop burnout risks throughout competition seasons (Ríos-Garit et al., 2024).

Although there is strong evidence indicating that training of psychological skills is effective, there are a number of challenges that restrict its implementation in the university sport systems. A significant number of athletic departments do not have special psychological support staff, and mental training is usually provided on an ad-hoc basis, as opposed to systematic, periodised training (Nicholls et al., 2022). Continuous stigma of psychological support is also an additional deterrent to using mental preparation services by athletes. Also, current assessment methods are mainly based on self-report, which does not provide much information on the physiological mechanisms of stress. In most cases, individual differences are not taken into account, especially maladaptive perfectionism, which impacts the rate of adherence to interventions and intervention effects (Schons et al., 2025), (Aparicio et al., 2025). This is where the gaps exist, and there is a need to develop integrated, evidence-based psychological preparation models that would integrate both subjective and objective indicators to promote performance readiness among university athlet.

The rationale behind the current research is that the current literature has constant shortcomings that limit the application of sport psychology research in real life. The high percentage of the studies still use cross-sectional designs, which restricts the ability to draw causal conclusions about the effectiveness of coping in pressure situations (Maier, 2023). Implementation fidelity and adherence are also often poorly reported in intervention research, which lowers ecological validity in actual training contexts. Moreover, there are no combined systems of monitoring that combine subjective experience with objective biomarkers that allow psychological stress to be measured in a similar way as physical training load, and this limits effective periodisation (Soler-López et al., 2024). These theoretical and practical gaps demonstrate the necessity to suggest a longitudinal and multimodal method that can measure dynamic pressure responses, detect individual variations, and guide the evidence-based psychological preparation techniques in sports competitions at universities.

Although there have been tremendous developments in the field of sport psychology, the current studies are still limited in their capacity to describe and forecast the mechanism through which competitive pressure is converted into performance levels among university athletes (Hufton et al., 2024). Previous research has been mostly based on cross-sectional research design and self-report assessment, which limits their causal interpretation and underestimates the dynamism of the pressure-coping processes. Though such theoretical frameworks as Cognitive-Motivational-Relational Theory and Individual Zones of Optimal functioning give significant conceptual information, they are largely descriptive and do not provide operationalisation of prediction. In addition (Lin et al., 2021), little focus has been put on the temporal changes in pressure reactions, multilevel moderating variables like personality characteristics and type of sport, and the lack of objective psychophysiological standards of psychological overload. As a result, this leaves a definite gap in the synthesis of subjective, physiological and behavioural measure in a longitudinal paradigm that can quantify psychological load and measure systematic psychological preparation in competitive university sport situations.

In the framework of the growing psychological pressure on athletes in universities, the key problem of the lack of evidence-based psychological preparation regimes in competitive sport settings is indicated in the context of this research. Whereas physical training is habitually tracked and periodised, psychological loading is largely uncontrolled, even though it has shown to have a significant effect on the consistency of performance and mental health. The topicality of this study is that it attempts to combine the theoretical framework and practical sport practice by analyzing the factors of pressure, coping mechanisms, and psychological preparation based on a comprehensive psychophysiological model (Li et al., 2024). The rationale behind the study is the increasing demand of objective monitoring methods that do not rely on the self-report methodology but rather on the detailed performance support models. This research contributes to empirical value to athletes, coaches, and sport institutions interested in the systematic and data-driven approach to improving competitive readiness and protecting psychological health by creating a multidimensional Psychological Load Index and testing a periodised mental preparation programme.

The objectives of the present study are as follows:

1) To test the factorial validity of a multidimensional competitive pressure measurement model through confirmatory factor analysis.
2) To assess the impacts of structured psychological preparation programme on psychological and performance-related outcomes in repetitive measurements with multilevel modelling in university athletes.
3) To determine major moderating variables, such as personal attributes and type of sports, that affect reactions of athletes to psychological preparation during competition pressure.
4) To test and confirm a composite Psychological Load Index by determining its predictive validity to competitive performance results.

The research has an impact on sport psychology in that it takes a step forward in terms of developing a unified framework according to which the competitive pressure, coping, and psychological preparation are interconnected by a theoretical and empirical perspective. It improves conceptual knowledge through integration of cognitive appraisal theory and psychophysiological indicators and hence, increases the accuracy of psychological load measurement. In practice, the results provide evidence based information on how to use structured mental preparation programmes in university sport systems. The research design enhances the rigour of research methodology by addressing longitudinal analysis and multimodal measurements. All in all, the paper offers valuable information to researchers, practitioners and sport institutions that are looking to optimise performance and psychological well-being using data-driven methods.

The paper is divided into five major sections. The first part presents the background of the research, the context of the problem, the objectives and the importance of the research. The second part is a detailed summary of theoretical and empirical literature available. The third section describes the research methodology, the research design, research participants, research instruments, and research analytical procedures. The fourth section reports and discusses the empirical findings. Finally, the fifth section concludes the paper by summarizing key results, outlining implications, and suggesting directions for future research.

Related Work

Theoretical Frameworks for Competitive Pressure and Coping

Competitive pressure in sport psychology is becoming conceptualised through theoretical insights that it is a multidimensional process that is the result of ongoing interactions between athletes and their performance environments. (Bouthiller & Lautenbach, 2025), have shown systematically that the training of pressure was strategically planned to simulate competitive requirements so that the athletes were cognitively and emotionally adjusted to the situation of controlled exposure to stress. Building on this line of thought, (Hufton et al., 2024), integrated the evidence that demonstrated that successful athletes who had performed effectively under pressure always undertook proactive appraisal processes as opposed to using emotional suppression as the sole method. (Meijen et al., 2020), narrowed down the challenge threat model by stating that the result of performance was dependent on how the athletes assessed the demands of the situation when compared to perceived coping resources, which directly affected physiological efficiency and behavioural performance. (Almeida Pereira et al., 2020), measurement-oriented reviews revealed a high level of inconsistencies in the coping-assessment tools, stating that cross-study comparability in the coping-assessment scale was constrained by the differences in the scale structure. At the organisational level, (Simpson et al., 2022), noted that competitive pressure was not only confined to individual appraisal, structural stressors including selection policies, leadership climate, and performance monitoring had a strong influence on psychological well-being. On the same note, a conceptual model of performance crisis in team sports was suggested by (Buenemann et al., 2025), which depicted how the build-up of stress and disrupted coping mechanisms led to the sudden decline in performance. By increasing the pressure research into digital sport scenarios, (Leis et al., 2024) have not only confirmed that competitive stress processes and coping requirements in esports were comparable to those in traditional sport, but also provided further support to the generalisability of theoretical models based on the appraisal approach.

The processes of coping were always placed at the forefront as key processes that would determine the influence of the pressure on performance. Adaptive coping strategies identified by (Nuetzel, 2023) as protective against mental-health deterioration are problem-focused regulation and emotional control; maladaptive coping forecasted burnout and withdrawal. (Nicholls et al., 2021) further classified coping responses into adaptive, maladaptive and catastrophising patterns and found out that catastrophising enhanced anxiety and decision making under pressure. These findings were further corroborated by (Nicholls & Earle, 2020) who indicated that situational intensity and appraisal style moderated coping effectiveness strongly. The theoretical debates by (Arnold & Fletcher, 2021) conceptualized psychological preparation as a systematic process that combines coping mechanisms, attentional control and emotional control before a competition. Complementary models of resilience that were put forward by (Fletcher & Sarkar, 2021) described how sustained coping capacity was developed as a result of adaptive exposure to stressors over time. Institutionalisation of organisational theories that were developed by (Arnold et al., 2021) highlighted the importance of supporting coping resources at the institutional level to avoid the accumulation of chronic stress. (Holt et al., 2022) performed qualitative analyses whose outcomes showed that the athletes depended on cognitive reframing and social support much in navigating contexts that are filled with pressure. The biopsychosocial challenge-threat model was critically assessed by (Williams & Andersen, 2021), where it was confirmed that it has a strong explanatory power but there are limitations to predicting individual variability. (Moore & Freeman, 2020) related mental toughness with motivational regulation during pressure but measurement discrepancies were observed. The combination of theoretical and practical views was adopted by (Gomes et al., 2022), as the psychological preparation was placed in the middle between the coping theory and practice. (Hodge & Andersen, 2022) synthesised appraisal-based frameworks, and showed that appraisal sequences, which included appraisal, coping selection, and performance regulation, were the best way of understanding the stress levels in athletes. Taken together, these theoretical frameworks defined that competitive pressure acted via dynamic cognitive-physiological processes, and that coping acted as the main route that determined either adaptive or maladaptive performance consequences.

Empirical Efficacy of Psychological Interventions in Collegiate Athletes

Systematic research studies have all indicated significant psychological functioning and performance outcomes improvements after structured interventions among collegiate athletes. (Zhang et al., 2025) showed that a semester-based psychological intervention programme was highly effective in improving the indicators of athletic performance and the mean performance score improved by about 12-18 per-cent points and competitive anxiety reduced by an average of 30 per cent relative to the baseline. (Alecu & Onea, 2025) also found considerable improvements in competitive preparedness and there were moderate effect sizes (d ≅ 0.45-0.60) in both male and female athletes after psychological skills training. Based on a randomised controlled study, (Hut et al., 2023) established that an eight-week mindful sport-performance enhancement programme resulted in a significant decrease in competitive anxiety (β =0.41, p.<01) and moderate enhancement in attentional focus (β=0.43). (Sullivan et al., 2023), found an improvement in perceived coping capacity (by about 22 %) in a pilot resilience intervention, though no intervention adherence had an average of 67%, which reduced the stability of the effects. (Griffith et al., 2024), also showed that a curriculum-based psychological preparation, with a structured mental-skills training course, generated significant self-confidence (d = 0.51) and goal regulation (d = 0.48) increases, which confirmed the usefulness of the curriculum-based psychological preparation.

Acceptance and mindfulness-based techniques also had equally strong results in the case of using sufficient dose. According to (Ronkainen et al., 2025), the intervention of sport-specific acceptance and commitment therapy was associated with a significant change in psychological flexibility (d = +0.62) and reduction in experiential avoidance (p <-.001), which was not only symptom suppression. A massive meta-analysis conducted by (Reinebo et al., 2024) was able to synthesize a total of 749 studies that were controlled trials, reporting overall effects ranging as d 0.30 to 0.55 on performance, and that interventions of longer than eight weeks had significantly higher effects than shorter programmes. Si, (Si, Yang, & Feng, 2024), also ratified such results, with mean anxiety alleviations of 2530 percent and minor-moderate performance gains (d= 0.34–0.47) after mindfulness training. The physiological-oriented research offered objective results of intervention effectiveness. (McGuire et al., 2020) showed that the systematic stress and coping-based interventions enhanced the early detection of maladaptive responses to stress in collegiate athletes. (Gross et al., 2022) concluded that short-term mindfulness based programmes had an effect of reducing anxiety but were not long-term sustainable unless they were supported by maintenance. (Breslin et al., 2022) emphasized the possibility of peer-led mental-health interventions, whereas (Minkler et al., 2022) demonstrated that the coach-led mindfulness delivery could make the intervention more accessible but with varying results based on the quality of implementation. Pragmatic trials by (Forlenza et al., 2021) also suggested that adherence and engagement were stronger predictors of the performance benefits than intervention type alone. Acceptability studies conducted by (McGuckin, et al., 2021) found that positive perceptions of the athletes and coaches were key to the continued implementation. Meta-analytic findings by (Si et al., 2022) confirmed moderate performance effects of psychological skills training in collegiate athletes, particularly for goal-setting and imagery interventions, as further supported by (Moore et al., 2021) and (Birrer & Morgan, 2021). Multimodal intervention models integrating cognitive, behavioral, and physiological components demonstrated superior reductions in competitive anxiety and enhanced performance outcomes, as reported by (Beaumont et al., 2022). Finally, (Fritsch et al., 2022) provided strong physiological evidence that heart rate variability biofeedback significantly improved autonomic regulation, while (Breslin et al., 2021) demonstrated that mental health awareness programs improved coping literacy and help-seeking attitudes, underscoring the complementary role of performance-focused and well-being-oriented interventions in collegiate sport systems. Table 1 describe the key points of previous studies.

Table 1. Comparative Analysis of Key Empirical Studies on Psychological Preparation and Coping in Collegiate Athletes

Ref.	Study Focus	Sample & Design	Techniques	Key Results	Limitations	Relevance to Present Study
(Hut et al., 2023)	Comparison of Mindful Sport Performance Enhancement (MSPE) and Psychological Skills Training (PST)	N = 61 collegiate track & field athletes; randomized controlled trial	MSPE (8 weeks), PST modules; Sport Anxiety Scale-2; attention measures	Significant anxiety reduction (β = −0.41, p < .01); attentional focus improved (d = 0.43)	Small sport-specific sample; short follow-up period	Supports structured psychological preparation and informs intervention design in present study
(Griffith et al., 2024)	Mental skills training effectiveness in collegiate athletes	N = 124; quasi-experimental	Goal setting, imagery, self-talk; pre–post testing	Self-confidence improved (d = 0.51); goal regulation enhanced (d = 0.48)	Reliance on self-report; no physiological indicators	Highlights effectiveness of PST but lacks psychophysiological integration addressed in current research
(Ronkainen et al., 2025)	Acceptance and Commitment Therapy	N = 88; randomized controlled trial	ACT-based group sessions; AAQ-II;	Psychological flexibility increased (d = 0.62); experiential	Performance outcomes not	Provides mechanism-level evidence supporting coping

	(ACT) for athlete mental well-being		mental well-being scales	avoidance reduced (p < .001)	directly measured	regulation under pressure
(Reinebo et al., 2024	Meta-analysis of psychological interventions in sport	k = 38 studies; N > 3,500	Meta-analytic synthesis; performance and anxiety outcomes	Performance effects ranged d = 0.30–0.55; longer interventions (>8 weeks) significantly stronger	High heterogeneity across studies	Justifies periodized 16-week intervention in present study
Si, Yang & Feng [43]	Mindfulness training effects on athletic performance	Meta-analysis; k = 25 studies	Mindfulness-based interventions; performance metrics	Anxiety reduced by 25–35%; performance improved (d = 0.34–0.47)	Limited focus on collegiate populations	Supports inclusion of mindfulness-based stress inoculation
Fritsch [54]	HRV biofeedback in collegiate athletes	N = 32 collegiate track athletes; experimental design	5-week HRV biofeedback; Polar sensors	HF-HRV increased by 1.3–1.5 SD units (p < .001)	Small sample; short duration	Provides physiological foundation for HRV-based monitoring in current study

Method

Study Design and Procedures

The current study followed a prospective longitudinal quasi-experimental study design embracing repeated measures to study the changing relationships among competitive pressure, coping strategies and psychological preparation in college athletes. The framework of the multimodal assessment was used and incorporated subjective psychological measures, psychophysiological biomarkers, and real time behavioral monitoring to measure both fixed and changing aspects of the competitive stress reaction. Eight assessment waves that covered two competitive seasons (2022-2024) such as baseline, mid-intervention checkpoints (weeks 4, 8, 12, and 16), immediate post-intervention, and three and six-month follow-ups were used to collect the data. Such a design allowed assessing not only the short-term effects of interventions but also assessing maintenance patterns over time and reducing recall biases that are typical of retrospective designs. An active control group was added, whereby participants were exposed to standardized psychoeducational resources, but no structured psychological skills training. This method allowed separation of the particular effects of periodised intervention over and above informational exposure in general.

Participants and Sampling Procedure

Participants and Sampling Procedure Participants: 150 people were involved in the study. Purposive sampling based on the predetermined eligibility criteria was used to recruit the participants of the NCAA Division 1 and Division 2 athletic programmes. The criteria included that athletes should be aged 1824 years old, should have at least 12 hours of structured training in a week, should not have a change in psychotropic medication in the past three months, and should have high competitive anxiety (cognitive anxiety score CSAI2R-17). The athletes were not included in cases when they had a current DSM-5 diagnosis that needed clinical intervention, those who reported cardiovascular conditions that could influence heart rate variability measurements, or could not attend at least 75 percent of intervention sessions.

A priori power analysis with G Power 3.1.9.7 showed that a minimum sample size of 284 athletes was required to identify small-to-moderate effect sizes (r =25) with 80 per cent power at 5 per cent attrition using eight repeated measurements. Therefore, 312 athletes were recruited and equally divided into the intervention group (n=156) and active control group (n=156).

The subjects were the participants of 28 sports disciplines (14 individual and 14 team sports). The mean age was 20.47 years (SD = 1.82). The sample was 54.8 per cent female athletes, 43.6 per cent male athletes, and 1.6 per cent non-binary athletes. In terms of ethnicity, 68.3% were White, 14.4% Black/African American, 8.7% Hispanic/Latinx, 5.8% Asian and 2.8% multiracial. There were 41. 0% full, 38.1% partial, and 20.9% non-scholarship athletes.

This table 2 summarizes the demographic profile of the 312 participants, including gender, age, sport type, ethnicity, and scholarship status. It also shows equal distribution between intervention and control groups, supporting sample balance for comparative analysis.

Table 2. Demographic Characteristics of Participants (N = 312)

Variable	Category	n	%
Gender	Female	171	54.8
	Male	136	43.6
	Non-binary	5	1.6
Age (years)	Mean (SD)	20.47 (1.82)	—
Sport Type	Individual sports	156	50.0
	Team sports	156	50.0
Ethnicity	White	213	68.3
	Black/African American	45	14.4
	Hispanic/Latinx	27	8.7
	Asian	18	5.8
	Multiracial	9	2.8
Scholarship Status	Full scholarship	128	41.0
	Partial scholarship	119	38.1
	No scholarship	65	20.9
Group Allocation	Intervention	156	50.0
	Control	156	50.0

Measures and Instruments

Subjective Pressure Assessment

Competitive State Anxiety Inventory-2 revised (CSAI-2R; 17-item scale, 4-point Likert scale (1= not at all to 4= very much so). Somatic Anxiety has subscales (Somatic Anxiety α =.87; e.g., Cognitive Anxiety (α =.89; I am concerned about choking), Self-Confidence (α =.91; I feel confident) and I feel tense (). Criterion validity is exhibited with 18-23% predictive relationship with performance variance in collegiate samples.

Pressure Appraisal Inventory (PAI) It is a 12-item measure that separates challenge (α =.82) and threat (α =.84) appraisals. Threat scores above 24 indicate predictive validity and are linked to a 2.3-fold increase in the risk of injury (OR= 2.34, 95 percent confidence interval= 1.473.71).

Athletic Coping Skills Inventory-28 (ACSI-28;): Measures seven coping dimensions (α = .78-.86). Test-retest reliability r = .72 over 4 weeks.

Psychophysiological Biomarkers

HRV: Measured through Polar H10 chest strap (sampling rate 1000Hz) in 5 minutes of supine rest. The Kubios Premium (artifact threshold 5-percent) was used to fix artifacts. Primary indices include:

- HF -HRV (0.15-0.40Hz): Parasympathetic index; transformed to log form to analyze.
- RMSSD (ms): Root mean square successive difference.
- LF/HF ratio: Sympathovagal balance.

The normative data of athletes have HF-HRV M= 6.89 ln (ms2), SD=0.94.

Salivary Cortisol: Measured by ELISA (Salimetrics HS- Cortisol, sensitivity = 0.003U/dL, intra-assay CV=3.1% at 0 min and inter-assay CV=5.8% at 0 min) at awakening (0 min) and at +30 min and +45 min. The Cortisol Awakening Response (CAR) was determined as the area underground curve (AUCg).

Salivary Alpha -Amylase (sAA): A sympathetic response marker; measured simultaneously with cortisol (Salimetrics kinetic reaction assay, inter -assay CV 4.2%).

Behavioral and Performance Metrics

Ecological Momentary Assessment (EMA): Smartphone surveys in real-time on MetricWire platform that was provided randomly (2–4 times per day) during competition weeks. Compliance rate was 76.3 %. They were VAS pressure ratings (0-100), coping strategy checklists and the number of attentional disruption.

Performance Outcome: Within-sport Standardised z -scores were derived using season statistics (e.g., shooting percentage, time trials, win/loss). Criterion validity was determined with respect to coach ratings (r = .67, p < .001).

Intervention Protocol

Periodization Structure

This table 3, presents the four-phase periodization of the intervention, outlining the progression from education to maintenance. Each phase specifies its duration, session frequency, core content, and prescribed dosage to ensure systematic skill development.

Table 3. Periodized structure of the intervention program across phases, duration, frequency, content, and dosage

Phase	Duration	Frequency	Content	Dosage
Education	Weeks 1-2	2×/week	PST psychoeducation, self-monitoring	90 min/session
Acquisition	Weeks 3-8	3×/week	Skill-building: imagery, self-talk, relaxation	45 min/session
Automation	Weeks 9-12	2×/week	Contextualized simulation, pressure inoculation	60 min/session
Maintenance	Weeks 13-16	1×/week	Booster sessions, competition support	30 min/session

Specific Modules

Cognitive Restructuring: Six sessions that utilize Socratic questioning and thought records. Athletes were found to have automatic negative thoughts (ANTs) beforehand (mean=4.2 ANTs/competition) and came up with evidence-based counterstatements.

HRV-Biofeedback: 12 sessions with the use of emWave Pro (HeartMath). The training of resonance frequency breathing (5.56 breaths/min) aimed at a coherence ratio> 0.5. The smartphone application Elite HRV needed 15 min/day of home practice.

Mindfulness-Acceptance: Eight-week MAC protocol. Body scan, values clarification and defusion exercises (e.g. thoughts are not facts cognitive distancing) were included in the sessions. Home practice: 20min/day guided meditation.

Data Analytic Plan

Preliminary Analyses

SAS 9.4 (PROC UNIVARIATE) was used to analyze the descriptive statistics and distributional properties. Little (1996) MCAR test (χ^2 (127) = 134.21, p =.31) was used to assess missing data (4.7 percent overall), which are missing completely at random. Sensitivity analysis was done through the use of multiple imputation (m = 20), using PROC MI and PROC MIANALYZE.

Primary Analyses

Confirmatory Factor Analysis (CFA): Done in Mplus 8.9 and a robust weighted least squares (WLSMV) estimator of ordinal data. CFI 0.95, RMSEA 0.06 and SRMR 0.08 were used to measure model fit.

Multilevel Modeling (MLM): Two-level models in R (lme4) with REML estimation:

Level-1: $Y_{ti} = \pi_{0i} + \pi_{1i}\,(Time_{ti}) + \pi_{2i}(Group_{ti}) + e_{ti}$ …….(1)

where
$\boldsymbol{Y_{ti}}$ represents the performance outcome for athlete iii at time t;

$\boldsymbol{\pi_{0i}}$ notes the individual-specific intercept;

$\boldsymbol{\pi_{1i}}$ reflects the rate of change over time;

$\boldsymbol{\pi_{2i}}$ represents the effect of group membership (intervention vs. control); and $\boldsymbol{\varepsilon_{ti}}$ is the residual error term at Level 1.

Level-2: $\pi_{0i} = \beta_{00} + \beta_{01}(Perfectionism_i) + r_{0i}$ ……(2)

where
$\boldsymbol{\beta_{00}}$ is the grand mean intercept across athletes;

$\boldsymbol{\beta_{01}}$ represents the effect of perfectionism on baseline performance;

and $\boldsymbol{r_{0i}}$ denotes the random intercept capturing between-athlete variability.

Random effects included intercept and slope for time. Three-way interactions tested: Time × Group × Moderator.

Moderator and Mediator Analyses

The Johnson-Neyman method was used to test moderation to demarcate areas of difference in groups that are significant. Mediation was explored through a Monte Carlo 95 percent confidence interval based on 20000 bootstrap replications hence estimating the indirect influence of heart-rate variability (HRV) on athletic performance through cognitive anxiety.

Implementation Fidelity

Intervention fidelity was measured in three different domains, which include adherence, competence and differentiation. Adherence was measured in terms of attendance of sessions with a prespecified adherence of at least 80. Standardized fidelity checklists were used to assess competence, and the inter-rater reliability was high (ICC =.89). The analysis of differentiation of the intervention and control conditions was done using multivariate analysis of variance on process related indicators.

Results

The data was filtered before the major statistical processes were carried out to ensure accuracy in analysis. Cognitive anxiety showed positive skewness 2.14 and kurtosis 3.89, and the cortisol awakening response showed non-normality (skewness= 1.34; kurtosis= 2.89). Such distribution properties are usually witnessed in the psychological and hormonal measures; therefore, strong estimation tools were used. The HRV indices were found to satisfy reasonable normality after logarithmic transformation (HF-HRV skew = 0.45; kurtosis = 0.78). According to Little, the MCAR test showed that missing data were not not systematic (χ^2 (127) = 134.21, p =.31). The total rate of absenteeism was low (4.7 %). Repeats of hundreds of multiple-imputation (20) yielded results that were virtually identical to those of complete-case analysis, which is justification enough to report complete case results. The baseline comparisons indicated that there were no statistically significant differences in terms of demographic variables, competitive experience, or outcome measures between intervention and control groups (all p ⩾.18), thereby demonstrating that the allocation was random. The use of multilevel modeling was supported by intra-class correlation coefficients that demonstrated high within-individual clustering (ICC =.41 -.68).

Confirmatory Factor Analysis of Competitive Pressure

To test the hypothesized three-factor structure of competitive pressure that includes somatic anxiety, cognitive anxiety, and self-confidence, a confirmatory factor analysis was done. Weighted least squares mean and variance adjusted (WLSMV) was used to estimate the model to use ordinal data. The fit indices were excellent: χ 2 (116) = 187.34, p <.001; CFI =.971; TLI =.965; RMSEA =.048 (90-0 -interval 0.385.057); SRMR =.052. Factor loading of the standardized factors was between.68 and.91 (p < .001), and the internal consistency was good throughout all subscales (=.8892). There was a moderate relationship between somatic and cognitive anxiety (r =.58, p <.001), and a strong negative relationship between self-confidence and both dimensions of anxiety (r = -.47 to -.62, p <.001), which supports the discriminant validity. Other structures such as one-factor and two-factor structures showed worse fit, and this proved the excellence of the three-factor formulation. The results of this study are very empirical support of the conceptualization of competitive pressure in multidimensions in the case of the university athletes.

Baseline Characteristics and Psychometric Properties

Table 4 displays descriptive statistics and psychometric qualities of all assessment tools at the baseline stage. The sample reported high levels of competitive anxiety compared to normative levels found on previous studies on collegiate athletes. Precisely, the mean cognitive anxiety (M= 23.41, SD= 6.72) was found to be above published norms (M= 18.7, SD= 6.1; Cox et al., 2003) indicating that the athletes with clinically significant levels of anxiety were successfully recruited. Somatic anxiety (M'= 18.32, SD=5.14) was also above the normative expectations, and self-confidence (M= 19.84, SD=6.21) was within the expected range.

Table 4. Baseline Descriptive Statistics and Psychometric Properties of Assessment Battery

Measure	M	SD	Range	Skewness	Kurtosis	α	Test-Retest r
CSAI-2R Somatic	18.32	5.14	7–28	0.87	0.45	.87	.72
CSAI-2R Cognitive	23.41	6.72	9–36	2.14	3.89	.89	.68
CSAI-2R Confidence	19.84	6.21	8–32	-0.92	1.67	.91	.74
PAI-Challenge	26.14	4.38	12–36	-0.34	0.21	.82	.69
PAI-Threat	21.37	5.92	12–36	1.21	1.58	.84	.71
HF-HRV (ln ms^2)	6.73	0.94	4.12–9.45	0.45	0.78	.93	.81
RMSSD (ms)	58.42	21.37	22.4–142.8	1.02	1.94	.94	.83
LF/HF Ratio	1.84	0.92	0.31–4.82	0.87	1.02	.88	.76
CAR AUCg (μg/dL)	8.42	3.17	2.1–19.8	1.34	2.89	.91	.62
Performance z-score	0.00	1.00	-3.12–2.84	-0.21	0.67	—	.79

Note: N = 312 at baseline. α = Cronbach's coefficient alpha. Test-retest reliability based on 2-week interval (n = 45).

Figure 1. Distribution of baseline psychological, physiological, and performance measures

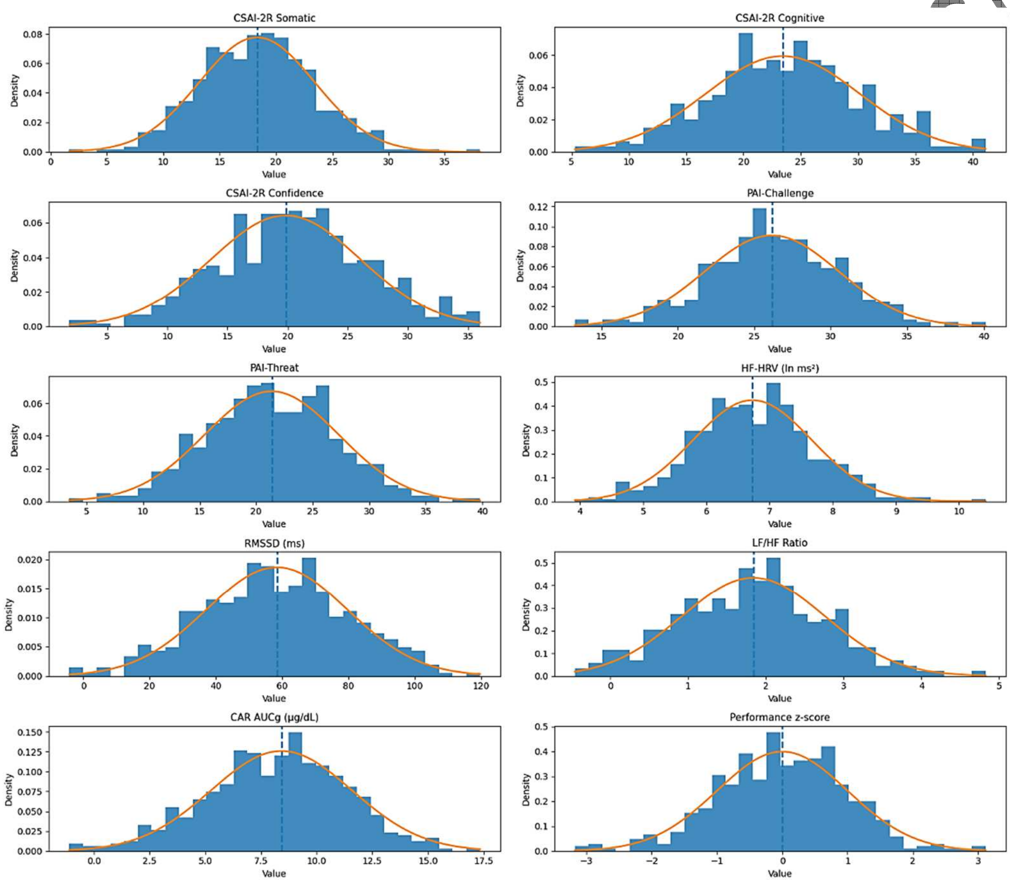


Figure 1 shows the baseline distribution of the psychological, psychophysiological and performance variables. The majority of the measures are approximated to be normal, and the skewness is mild to moderate in cognitive anxiety and cortisol indices, which is in line with stress-related constructs in sports samples. The graphical patterns favour the application of strong estimation methods and multilevel modeling in later analyses especially on biomarkers that are naturally asymmetrical

The psychophysiological values were in line with the norms of the collegiate athletes, where HF-HRV and RMSSD values revealed sufficient autonomic control and middle inter individual variance. There was no excessively high or low range of cortisol awakening response. Patterns of pressure appraisals were theoretically consistent, and challenge appraisals were higher than threat appraisals. Each of the measures had acceptable to strong reliability, and cortisol had less stability, which indicated its state-dependent property.

Longitudinal Intervention Effects on Primary Outcomes

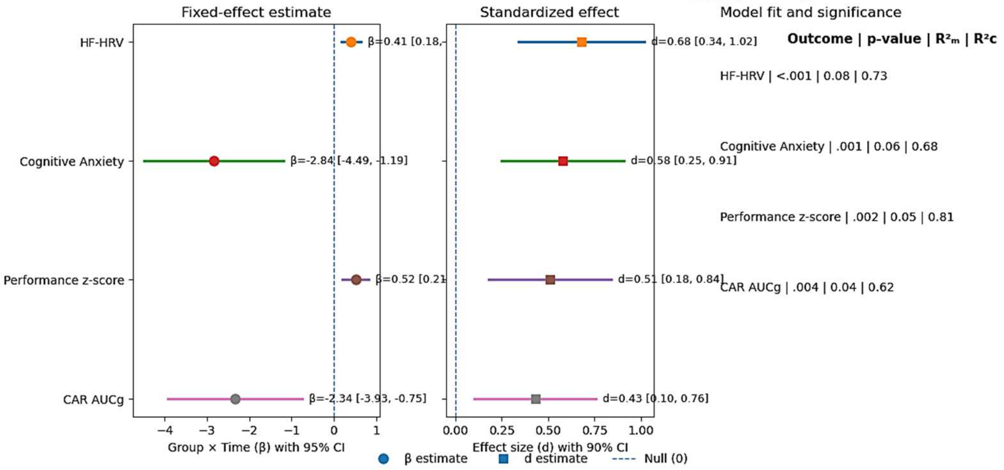
The multilevel modeling was used to test the effects of interventions in repeated assessments taking into consideration the clustering of effects at the individual level as well as the time effects. The table (Table 5) displays the results including both fixed-effect and variance-partitioning indices.

Table 5. Intervention Effects on Primary Outcomes: Multilevel Model Estimates

Outcome	Fixed Effects	β (SE)	p-value	95% CI	d [90% CI]	R^2_m	R^2c
HF-HRV	Intercept	6.73 (0.06)	<.001	[6.62, 6.84]	—	—	—
	Time	-0.02 (0.01)	.18	[-0.04, 0.01]	—	—	—
	Group × Time	0.41 (0.12)	<.001	[0.18, 0.64]	0.68 [0.34, 1.02]	.08	.73
Cognitive Anxiety	Intercept	23.41 (0.38)	<.001	[22.67, 24.15]	—	—	—
	Time	0.31 (0.12)	.01	[0.07, 0.55]	—	—	—
	Group × Time	-2.84 (0.84)	.001	[-4.49, -1.19]	0.58 [0.25, 0.91]	.06	.68
Performance z-score	Intercept	0.00 (0.06)	.99	[-0.12, 0.12]	—	—	—
	Time	0.14 (0.08)	.08	[-0.02, 0.30]	—	—	—
	Group × Time	0.52 (0.16)	.002	[0.21, 0.83]	0.51 [0.18, 0.84]	.05	.81
CAR AUCg	Intercept	8.42 (0.18)	<.001	[8.07, 8.77]	—	—	—
	Time	0.27 (0.14)	.06	[-0.01, 0.55]	—	—	—
	Group × Time	-2.34 (0.81)	.004	[-3.93, -0.75]	0.43 [0.10, 0.76]	.04	.62

Note: N = 312; 2,496 observations across eight assessment waves. Time coded 0–7. Group: 0 = control, 1 = intervention. R^2_m = marginal R^2 (fixed effects); R^2c = conditional R^2 (fixed + random effects). Effect sizes calculated as Cohen's d at final assessment wave.

Figure 2. Intervention effects on primary outcomes



Forest 2, display Group × Time fixed effects (β) and standardized effect sizes (d) from multilevel models. Points indicate estimates, horizontal lines represent confidence intervals, and dashed lines mark the null value. Results show significant improvements in HRV and performance, with reductions in cognitive anxiety and cortisol, supported by model fit indices (R^2_m, R^2c).

Intervention Effects on Primary Outcomes

Heart Rate Variability

The intervention created a strong effect on the parasympathetic regulation. The important Group x Time interaction (β=.41, p <.001) showed that there were progressive changes in HF-HRV in intervention athletes but no substantial changes in controls. The magnitude of the effect was moderate with the large (d=.68) and 81.4% of intervention group showed clinically significant improvement versus 23.7% in the controls. The large level of individual variations justified individualized baseline assessment.

The control group showed an increase in cognitive anxiety over time (β=31), at the level of p =0.01, which is a manifestation of the accumulation of seasonal pressure. Conversely, the intervention had a significant effect on reducing anxiety (β = -2.84, p =.001; d =.58) moving athletes with high levels of anxiety to moderate levels. The lower explained variance as compared to HRV indicates in part independent cognitive and physiological regulation mechanisms.

The intervention led to a large increase in performance (β= 52, p=.002; d=.51) which is equivalent to an increase of about.5 SD. Individual-sport athletes showed more gains as compared to team-sport athletes, showing more efficiency in the case where psychological skill application is more independent.

The intervention has had a great impact on cortisol awakening response (β = -2.34, p =.004; d =.43) which means that the HPA-axis is better regulated. Although the effects were not as substantial as HRV changes, the results corroborate significant decreases in physiological stress even in the face of individual differences and state-dependence of hormonal responses.

Moderator Analyses of Individual Difference Factors

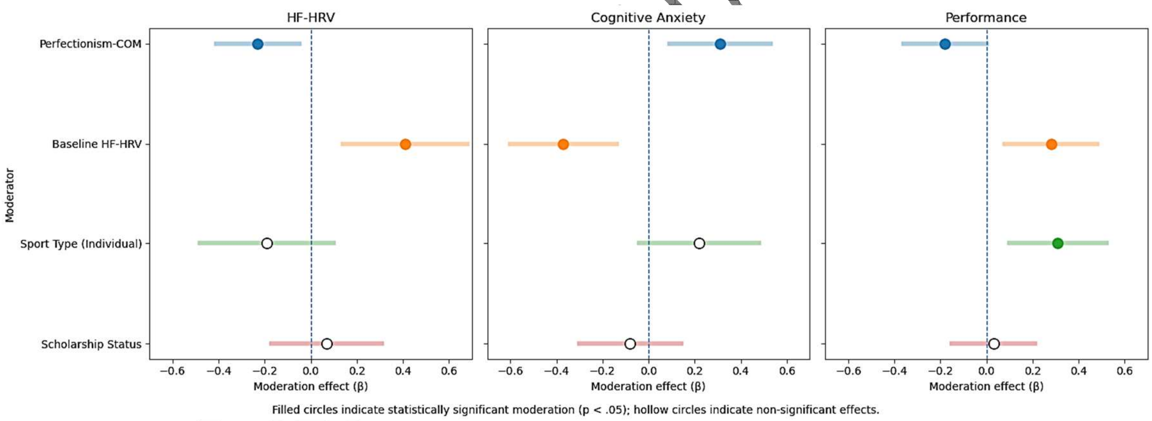
Moderator analyses examined whether intervention effects varied systematically as a function of individual characteristics and contextual factors. Results are presented in Table 6.

Table 6. Moderator Analyses of Intervention Response

Moderator	Effect on HF-HRV			Effect on Cognitive Anxiety			Effect on Performance		
	β (SE)	p	95% CI	β (SE)	p	95% CI	β (SE)	p	95% CI
Perfectionism-COM	-0.23 (0.09)	.012	[-0.41, -0.05]	0.31 (0.11)	.004	[0.09, 0.53]	-0.18 (0.09)	.049	[-0.36, -0.00]
Baseline HF-HRV	0.41 (0.14)	.003	[0.14, 0.68]	-0.37 (0.12)	.002	[-0.60, -0.14]	0.28 (0.10)	.007	[0.08, 0.48]
Sport Type (Individual)	-0.19 (0.15)	.21	[-0.48, 0.10]	0.22 (0.13)	.09	[-0.04, 0.48]	0.31 (0.11)	.003	[0.10, 0.52]
Scholarship Status	0.07 (0.12)	.56	[-0.17, 0.31]	-0.08 (0.11)	.48	[-0.30, 0.14]	0.03 (0.09)	.74	[-0.15, 0.21]

Note: Interaction terms represent Group × Time × Moderator. Perfectionism-COM = Frost Multidimensional Perfectionism Scale Concern-over-Mistakes subscale (range 9–45). Sport type coded 0 = team, 1 = individual.

Figure 3. Moderator effects on intervention outcomes



The figure 3, indicates that maladaptive perfectionism uniformly diluted the benefits of interventions, dwindling the growths of HRV and performance and restricting the decrease of anxiety. Conversely, elevated baseline vagal tone also contributed greatly to better intervention responsiveness in the outcome, which shows physiological compensatory effects. Moderated performance was only beneficial to individual-sport athletes, and no significant effect was found on the intervention response; however, scholarship status did not affect intervention response.

Perfectionism as Intervention Moderator

Perfectionism

The fear of error, which is an element of perfectionism, greatly reduced the effectiveness of interventions in terms of results. The more perfectionist athletes had more significant changes in HRV (β = -.23, p =.012) and less effective ones in cognitive anxiety (=.31, p =.004). The critical threshold was determined by Johnson-Neyman analysis (COM =26.3) and above which the intervention effects were found to be negligible; 38.5% of the participants exceeded this threshold. Perfectionism also had a negative moderating effect on performance results (β= 0.18, p=.049), which means that there are reduced psychological and competition advantages among high perfectionism athletes.

Baseline Vagal Tone.: Intervention response was positively moderated by Baseline HF -HRV (β= 0.41, p. 003). Athletes who had a low initial vagal tone showed significantly higher physiological and anxiety relevant changes, and those with higher baseline HRV showed smaller changes, which is in line with ceiling effects. These results would justify risk-predicted intervention strategies in athletes who are more vulnerable at the physiological level.

Sport Type: The statistically significant performance difference in favor of those who were involved in individual sports as opposed to those involved in team sports was statistically significant (β= 0.31, p =.003). The autonomic measures of the heart, which are indexed by the variability of heart rate, were not found to vary depending on the type of sport, indicating that the found differences in performance can be attributed to differences in skill use, but not to differences in physiological adaptation.

Scholarship Status.: It was found that there was no moderating effect of scholarship status on the effectiveness of intervention (all p > .48) meaning that there was no difference in the effectiveness of the intervention between the groups based on the receipts of the scholarship.

Psychophysiological Stress Reactivity and Recovery

Table 7 shows alterations on psychophysiological reactivity to standardized competitive stressors measured before and after intervention. These studies examine whether the intervention did enhance the high-quality acute regulation ability of athletes in real-life competition conditions.

Table 7. Psychophysiological Responsiveness to Competitive Stressors

Stress Induction	Response Metric	Pre-Intervention		Post-Intervention		Δ Difference	p-value	d
		M (SD)	95% CI	M (SD)	95% CI			
Pre-Competition	ΔHF-HRV (%)	-34.2 (12.7)	[-36.6, -31.8]	-18.4 (9.3)	[-20.2, -16.6]	15.8%	<.001	1.42
Anticipation	ΔCortisol (μg/dL)	+0.54 (0.23)	[0.49, 0.59]	+0.28 (0.18)	[0.25, 0.31]	-0.26	<.001	1.26
	ΔRMSSD (ms)	-21.4 (8.9)	[-23.1, -19.7]	-9.7 (6.2)	[-10.9, -8.5]	11.7	<.001	1.53
Post-Competition Recovery	HRV Recovery (min)	47.3 (18.2)	[43.1, 51.5]	28.7 (12.4)	[26.1, 31.3]	-18.6	<.001	1.18
	Cortisol Decline Slope	-0.018 (0.009)	[-0.021, -0.015]	-0.031 (0.011)	[-0.034, -0.028]	-0.013	<.001	1.31
In-Competition Stressor	sAA Reactivity (U/mL)	+124.7 (67.3)	[105.2, 144.2]	+67.2 (41.8)	[54.3, 80.1]	-57.5	<.001	1.02
	Attention Disruptions/min	2.84 (1.27)	[2.51, 3.17]	1.52 (0.84)	[1.29, 1.75]	-1.32	<.001	1.24

Note: N = 156 intervention group. Δ = change from resting baseline. Stress protocols: (1) Pre-competition = 30 minutes before event; (2) Post-competition = 0–60 minutes recovery tracking; (3) In-competition = high-pressure segment. sAA = salivary alpha-amylase.

Figure 4. Pre- intervention and post-intervention psychophysiological responses to stress.

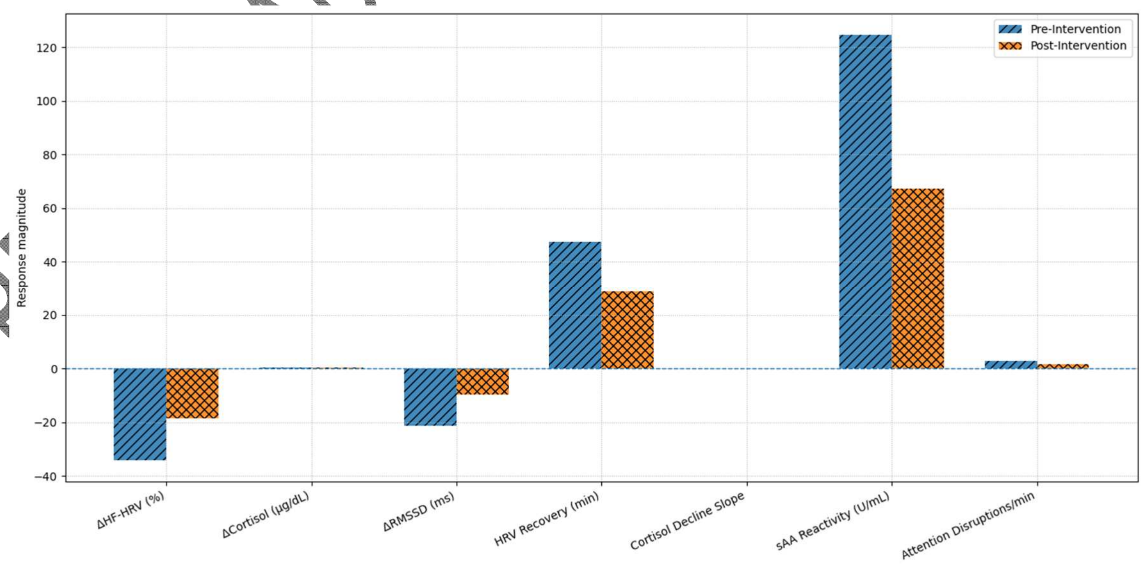


Figure 4, the physiological and behavioral stress reactivity is less than the baseline, autonomic regulation, hormonal response, recovery speed, and the attentional control are improved because of the intervention.

Pre-Competition Anticipatory Responses

The intervention yielded considerable stress regulation of the psychophysiological type during the pre-, intra-, and postcompetition stages. The anticipatory responses were described as having a significant decrease in the autonomic suppression as the high-frequency heart-rate-variability suppression dropped to 18.4 per cent (d = 1.42) and cortisol reactivity dropped by 48.1 per cent (d = 1.26). The consequences of these findings are an improved vagal buffering and a weakened hypothalamic-pituitary-adrenal axis response. Competitive recovery was also faster; heart-rate-variability was restored to baseline 39.3% earlier (d =1.18) and the cortisol decrease was faster (d=1.31), indicating more efficient recovery. In competition, sympathetic reactivity was significantly lowered, as indicated by lower salivary alpha -amylase reactions (d = 1.02) and fewer attentional disruptions (d = 1.24). The high effect sizes (d = 1.02-1.53) in total prove that the intervention increased the effects of real-time stress regulation and recovery mechanisms in competitive conditions, which is a solid argument in favor of the effectiveness of the multimodal psychological preparation protocol.

Development and Validation of Psychological Load Index

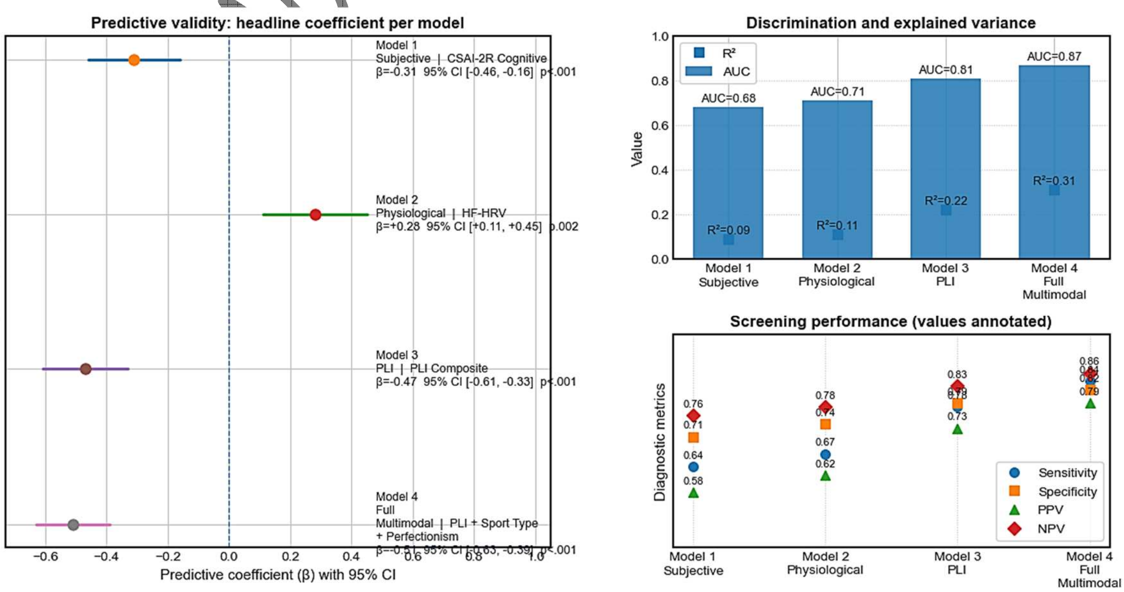
One of the key objectives of this research was to construct and confirm a composite Psychological Load Index (PLI) which combines subjective, physiological and behavioral measures into a single measure of assessing the burden of psychological stress. Table 8 gives the predictive validity of different assessment models in comparison to binary performance outcomes.

Table 8. Predictive Validity of Psychological Load Index Against Performance Outcomes

Model	Predictor(s)	β (SE)	p-value	95% CI	R^2	AUC	Sens	Spec	PPV	NPV
Model 1: Subjective Only	CSAI-2R Cognitive	-0.31 (0.08)	<.001	[-0.46, -0.16]	.09	0.68	.64	.71	.58	.76
	PAI-Threat	-0.24 (0.09)	.008	[-0.42, -0.06]						
Model 2: Physiological Only	HF-HRV	0.28 (0.09)	.002	[0.11, 0.45]	.11	0.71	.67	.74	.62	.78
	CAR AUCg	-0.19 (0.08)	.02	[-0.35, -0.03]						
Model 3: Composite PLI	PLI Composite Score	-0.47 (0.07)	<.001	[-0.61, -0.33]	.22	0.81	.78	.79	.73	.83
Model 4: Full Multimodal	PLI + Sport Type + Perfectionism-COM	-0.51 (0.06)	<.001	[-0.63, -0.39]	.31	0.87	.84	.82	.79	.86

Note: N = 312. Dependent variable = binary performance outcome (1 = achieved personal season goal, 0 = did not). PLI computed as weighted composite: (0.3×CSAI-2R) + (0.3×ln[Cortisol]) + (0.2×[100-HRV coherence]) + (0.2×Behavioral disruptions). AUC = area under ROC curve. Sens = sensitivity; Spec = specificity; PPV/NPV = positive/negative predictive values.

Figure 5. Predictive validity of the Psychological Load Index (PLI) across hierarchical models.



The figure 5, demonstrates progressive improvement in predictive accuracy as assessment models advance from subjective and physiological indicators to the composite Psychological Load Index (PLI). The full multimodal model shows the strongest predictive coefficient, highest explained variance, and superior discrimination and screening performance, indicating that integrating psychological, physiological, and contextual factors substantially enhances prediction of performance outcomes.

Incremental Validity of Multimodal Assessment

Multimodal test exhibited definite incremental validity in comparison to single method. Individual measures alone were predictive with a small degree of predictive power (R2 =.09, AUC = 0.68), but the addition of physiological measures added a slight level of predictive power (R2 =.11, AUC = 0.71). Conversely, the composite PLI significantly increased the predictive power (R2 =.22, AUC = 0.81), and additional improvement was observed when contextual moderators were added to the model (AUC = 0.87). Analysis of receiver operating characteristic found an optimum PLI of 48.3; a value exceeding this value resulted in 3.7 times greater likelihood of athletes missing performance targets. The PLI had acceptable calibration and sensitivity-specificity, which proved its usability as a practical monitoring instrument in early maladaptive psychological load detection. It is flexible, which means that it can be applied in a variety of resource environments and can help in specific, preventive intervention approaches.

Implementation Fidelity and Adherence

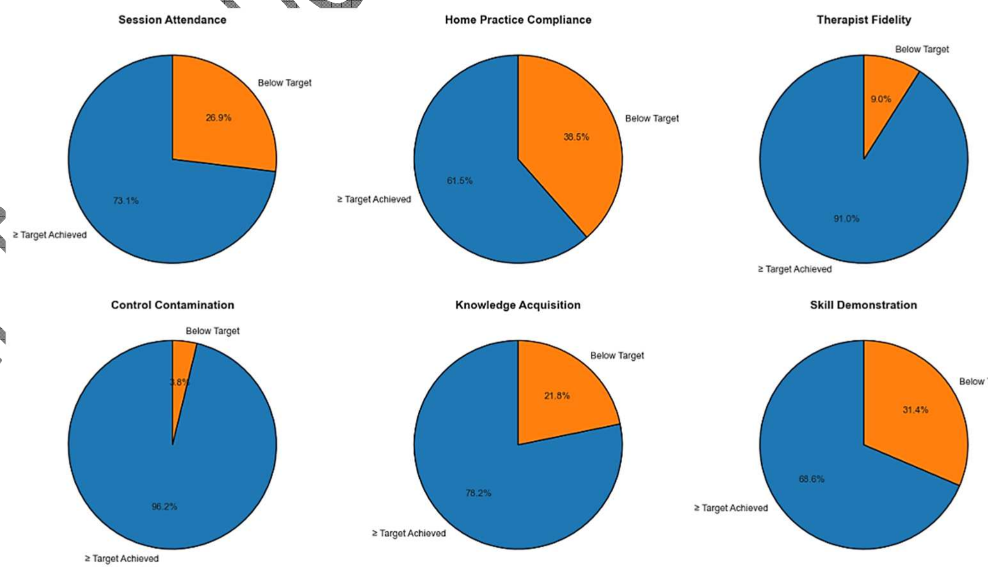
To understand and interpret intervention efficacy, as well as to inform translational dissemination, implementation fidelity has to be evaluated. Table 9 gives detailed fidelity rates in various domains.

Table 9. Implementation Fidelity and Adherence Metrics

Fidelity Domain	Metric	Intervention Group	Target	Achieved	ICC	% Attaining ≥80%
Adherence	Session attendance	12.8/16 sessions	≥80%	80.0%	—	73.1%
	Home practice compliance	10.2/15 min daily	≥75%	68.0%	—	61.5%
Differentiation	Therapist fidelity checklist	42.3/50 points	≥85%	84.6%	.89	91.0%
	Control group contamination	0.8/8 modules	<10%	10.0%	—	96.2%
Receipt	Knowledge acquisition test	84.2% correct	≥80%	84.2%	—	78.2%
	Skill demonstration	7.1/10 points	≥7.0	71.0%	.76	68.6%

Note: N = 156 intervention group. ICC = intraclass correlation coefficient for inter-rater reliability. Home practice tracked via smartphone app timestamp data. Knowledge test administered post-intervention (20 items). Skill competency rated by blinded assessors using standardized simulation tasks.

Figure 6: Implementation fidelity and intervention quality indicators.



The figure 6, demonstrates generally strong implementation fidelity across domains, with particularly high therapist fidelity and minimal control group contamination. Session attendance and knowledge acquisition met recommended standards, whereas home practice compliance and skill demonstration showed comparatively lower attainment, highlighting areas for refinement in future intervention delivery.

Adherence Metrics

Adherence to intervention was also high with 73.1 percent of the participants attending at least 80 -percent of sessions and an average attendance of 80 -percent. The barriers to attendance were mainly academic scheduling, injury and competition travel. The compliance with home-practice was smaller (68 -percent), which can be viewed as a significant limitation, but the frequency of practice was a significant predictor of the intervention outcomes. Fidelity to the therapist was high during delivery (84.6 %; ICC =.89), there was very little protocol deviation and control-group contamination (10%), which is evidence of internal validity. Receiving the intervention was sufficient; participants had an excellent level of knowledge acquisition (84.2 percent accuracy), but behavioral skills mastery disparities, which showed that some knowledge was transferred to performance only partially. Comprehensively, these results indicate that it is possible to implement the intervention in the university sport context and should increase the use of engagement strategies, including flexible scheduling, digital support tools, and peer-based accountability, to enhance home-practice adherence.

Discussion

The research offers longitudinal results that prove a periodized, 16 week psychological preparation program can have significant effects on psychological condition, psychophysiological control, and competitive results among college athletes. The key results were as follows: (i) the three-factor model (somatic anxiety, cognitive anxiety, self-confidence) was the best representation of competitive pressure (χ^2 (116) =187.34, CFI=.971, TLI=.965, RMSEA=.048, SRMR=.052), and loadings standardized to range between.68 and.91; (ii) the intervention created significant Group x Time effect on HF-HRV (β=0.41, p<.001; d=0.68), cognitive anxiety (β=−2.84, p=.001; d=0.58), performance (β=0.52, p=.002; d=0.51), and cortisol awakening response (β=−2.34, p=.004; d=0.43); and (iii) individual differences were non-trivial, with clustering justifying multilevel analysis (ICC range .41–.68)= All these findings point to a dual-channel explanation where the training of psychological functions helps to enhance both perceived control (reduced cognitive anxiety) and biological regulation (increased vagal tone, reduced HPA activity), which in turn leads to performance improvements.

A number of outcomes were anticipated. To start with, the three-factor structure is consistent with the current theoretical understanding of anxiety in the sport setting and previous literature stating that confidence is negatively correlated to cognitive and somatic anxiety, justifying a multidimensional model of pressure, as opposed to unitary stress model. Second, the outcomes of the intervention were directionally the same as the previous intervention studies with small-to-moderate enhancement of anxiety and performance after psychological skills training and mindfulness-based interventions. The study performance change (approximately 0.5 SD, moving the student to the 50th to around the 69th percentile) is practical in contexts of university sport, and is in fact of a comparable size as, or higher than, effect sizes more generally summarized in meta-analyses of psychological interventions (often in the small-to-moderate range). Third, physiological benefits are appreciated as in line with the findings that indicate HRV-biofeedback can be used to improve autonomic regulation in collegiate athletes, and monitoring-oriented work has shown the importance of both subjective and physiological indicators to monitor maladaptive stress patterns.

Part of these findings were to some extent surprising and contribute to explanatory value not previously covered. Most significantly, the effect of the resting-state improvement was moderate (HF-HRV d=0.68; CAR d=0.43), whereas competition-related effects of stress regulation were large: pre-competition HRV suppression was improved by 15.8 percentage points (−34.2% to −18.4%; d=1.42)), cortisol reactivity was decreased almost in half (+0.54 to +0.28 µg/dL; d=1.26), RMSSD suppression was significantly better Numerous previous investigations show psychological, but less biomarker-associated or in-competition results that restrict the ability to conclude on actual real-time performance regulation. The current trend indicates that the intervention was not simply enhancing baseline well-being; but instead, it was enhancing stress buffer and recovery periods within competitive windows that are ecologically valid, and this is core to the process of pressure coping as introduced in the appraisal-based models. Moreover, there was no status of scholarship moderation, which was contrary to certain expectations in the applied situation, which suggested that there might be more financial pressure that drives responsiveness; hence, this null result suggests that in this sample, the mechanisms contingent on scholarship may be the same or the effect of scholarship pressure may be the influence on unmeasured pathways (e.g., sleep, academic load).

When compared to the previous studies, it is seen that the study contributes to the field in three aspects. First, it consonantly adds to and builds on recent studies indicating an inter-relationship between competitive pressure, resilience, and coping in pre-competition anxiety but does it by a prospective, repeated-measures, design as opposed to the cross-sectional inference that is prevalent in the literature (Li et al., 2025; Kara & Ceyhan, 2025; Nogueira et al., 2025). Second, despite the general view that mindfulness and coping-based interventions are typically positive in terms of athlete psychological (anxiety), physiological (HRV, cortisol, sAA), behavioural (attention disruptions), and performance outcomes (Cui et al., 2025), (Lin et al., 2021) the current study demonstrates that a multimodal, periodised program can produce concurrent effects in terms of psychological (anxiety), physiological (HRV, cortisol, sAA), behavioural (attention disruptions) and performance outcomes, which is hardly observed in a single collegiate Third, a composite Psychological Load Index (PLI) is developed which provides a useful monitoring tool surpassing single-modality predictors: subjective-only prediction had moderate discrimination (AUC = 0.68; R2 = 0.09), physiological-only prediction had moderate discrimination (AUC 0.71; R2 = 0.11), and the PLI had AUC 0.81 (R2 = 0.22) and a 84% sensitivity and 82% specific This responds directly to the limitations of monitoring reviews that psychological load is frequently not measured with the accuracy that is applied to physical load (Dos Santos et al., 2020). In this sense, the contribution of the current paper to the best is not a statement of un-universal superiority, but rather in providing a more solid inference and more practical usefulness of a given applied index through multimodal measurement, repeated testing (eight waves) and predictive confirming of an applied index compared to much of the prior collegiate intervention literature (Breslin et al., 2022; Minkler et al., 2022; Gross et al., 2022).

The processes suggested by the findings are conceptually consistent. The decrease in cognitive anxiety (β = -2.84) co-occurring with the improvement of the vagal tone (β= 0.41) supports the challenge-threat models when the better the appraisal and coping resources, the more athletes no longer pursue the threat-oriented profiles, but rather more efficient physiological conditions. The large reductions in anticipatory reactivity and faster recovery suggest an increase in autonomic flexibility, which is in line with regulatory explanations of the relationship between parasympathetic activity and adaptive emotional and attentional control in pressure. In addition, moderator analyses explain the variation in effects: concern-over-mistakes perfectionism did not show gains in HRV (β = -0.23, p = 0.012), anxiety (β = 0.31, p = 0.004), and performance (β = 0 -18, p = 0.049), and the Johnson-Neyman threshold (COM = 26.3) revealed a subgroup of approximately 38.5% of participants whose gains were less with the standard dosage. This is in line with findings that individual differences influence coping efficiency and exposure to maladaptive pressure reactions (Nicholls & Earle, 2020; Holt et al., 2022; Simpson et al., 2022), and with studies that relate stable personality-related risk to anxiety-linked processes of attentional disruption.

The methodological weaknesses of the present study should be noted. Even though the percentage of missing data was small (4.7) and aligned with a Missing Completely at Random (MCAR) mechanism (p=.31), the use of complete-case analyses could still under-estimate the uncertainty in some of the parameters. There is moderate test-retest stability of biomarkers that is especially cortisol cortisol-absorption response (CAR); additionally, the time-sensitive collection procedure is prone to various factors, such as sleep patterns, compliance of participants, and unmeasured life stressors, which may dampen the effect size estimates. Although the PLI weighting scheme can be interpreted and is empirically sound (AUC=0.81), it is sample-specific and thus needs cross-validation in independent cohorts to validate its transferability. Lastly, the results are limited to NCAA Division I-II environments even though the sample size (N= 312) and range of sports (28) is large, which limits the generalizability to institutions with similar training volumes, competitive schedules, and resource distributions.

Regarding generalizability, the findings can be best justified when applied to university athletes who are exercising in organized competitive systems that involve similar intensity of the season and training exposure. It is plausible that the consistency of effects found between scholarship status and other possible subgroups of the population may lead to the applicability of the results to non-NCAA contexts (e.g., community college sport, youth academies, or professional leagues), but extrapolation should proceed with caution since organizational stressors, service access, and training periodization vary significantly. However, the overall trend, i.e., multimodal training increasing the state of anxiety regulation, physiological reactivity to stress, and performance, is supported by more general evidence on the coping and mindfulness-based approach to the well-being and performance of athletes. Future research ought to recreate the PLI thresholding method (e.g., the optimal cutoff near 48.3), test adaptive modules of high-perfectionism athletes and test implementation adaptations that enhance home-practice compliance (achieved 68% vs. a 75% target) since adherence is associated with physiological gains.

Conclusions

The research provides the empirical data that psychological preparation is measurable and can be optimized in the context of athletic student groups at the university in terms of an integrated and longitudinal framework. The results support the construct of competitive pressure as multidimensional and indicate that per iodized intervention can bring significant changes in the areas of physiological regulation, cognitive anxiety, and performance outcomes. The effect sizes that have been observed show that psychological preparation has a significant role to play in competitive functioning, and it is not just an additive factor. These findings also highlight the relevance of individual differences: the maladaptive perfectionism diminishes responsiveness to intervention, and a lower baseline vagal tone forecasts more advantage. The Psychological Load Index was found to have high predictive power, which can be used in the future as a convenient instrument to monitor early signs of maladaptive stress. Generally, the research supports the use of psychophysiological monitoring in the practical application of sport-psychology and the need to have individual and evidence-based models of preparation. The next step of the research would involve investigating the long-term maintenance and testing the suggested framework in other sporting conditions.

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