BMC Psychology

RESEARCH

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Longitudinal effects of stress in an academic context on psychological well-being, physiological markers, health behaviors, and academic performance in university students

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Abstract

Background Stress in academic settings arises from the interplay between perceived demands such as exams, deadlines, and academic workload and an individual's coping resources. While academic stress (AS) is frequently examined as a separate construct, the stress encountered in an academic environment encompasses both academic and non-academic stressors that students face throughout their university experience. This study examined the longitudinal associations between stress in an academic context on key psychological, physiological, and behavioral variables in university students.

Methods A longitudinal study was conducted with 115 Colombian psychology students aged 16 to 35 years, evaluated at the beginning and end of an academic semester. Variables were measured using validated psychometric questionnaires, including the Big Five inventory, the Zung Depression Scale, the UCLA Loneliness Scale, the State-Trait Anxiety Inventory (STAI), the Acceptance and Action Questionnaire (AAQ-II), the Perceived Stress Scale-4 (PSS-4). Behavioral data, such as physical activity, sleep patterns, and academic performance, were also recorded. Heart rate variability (HRV), a widely used physiological marker of autonomic nervous system function and stress regulation, was assessed. Paired t-tests were used to compare baseline and final measurements, and multiple linear regression determined predictors of academic performance.

Results Longitudinal analysis revealed significant declines in sleep duration, quality, and heart rate variability (HRV), alongside increased anxiety and depressive symptoms, indicating heightened stress and autonomic dysregulation. Despite these adverse effects, academic performance improved. This pattern suggests a complex association where higher achievement coincided with declining well-being markers. Regression models identified depressive symptoms

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as negative predictors of performance, while greater HRV (SD1, PNN50) and balanced autonomic activity were positively associated with academic performance.

Conclusions This study examines the longitudinal effects of stress within an academic environment on the psychological, physiological, and behavioral outcomes of university students. The findings showed compromised sleep patterns, changes in autonomic regulation, and mental health indicators; nevertheless, an increase in academic performance is also noted. However, this enhancement coincides with heightened levels of anxiety, depressive symptoms, and physiological dysregulation. These results highlight the necessity for targeted interventions aimed at fostering resilience and promoting a holistic sense of well-being.

Keywords Stress, Sleep, Heart rate variability, Psychological flexibility, University students

Introduction

Stress is an adaptive neuroendocrine response to demands perceived as challenging or threatening. It triggers the release of catecholamines (adrenaline, noradrenaline) and glucocorticoids (cortisol), which enhance alertness, energy levels, and concentration [1, 2]. This response allows individuals to maintain focus and perform optimally during demanding tasks, such as examinations, presentations, or athletic competitions [3]. When stress is short-term, perceived as manageable, and within the individual's capacity to address the specific challenge, it can have positive effects. These include supporting emotional and cognitive development, as well as promoting the acquisition of problem-solving skills, adaptability, and resilience. However, when external demands exceed available coping resources, stress can become maladaptive, negatively affecting physical and psychological health [4, 5]. Prolonged exposure to stress is associated with disruptions in essential systems such as the cardiovascular, immune, endocrine, nervous, and gastrointestinal systems, and may impair cognitive functions like executive attention, working memory, and decision-making [6]. Physiological consequences include oxidative stress, chronic low-grade inflammation, metabolic dysregulation, and increased risk of non-communicable diseases (e.g., cardiovascular conditions, metabolic syndrome) [7, 8]. At the psychological level, stress manifests as fatigue, tension headaches, feelings of guilt, emotional exhaustion, and depressive symptoms. Additionally, it is frequently associated with disruptions in sleep architecture, which involve both psychological and physiological mechanisms [9, 10].

In the academic context, stress arises from the interaction between perceived demands (e.g., exams, deadlines, academic workload) and the individual's coping resources [11, 12]. While academic stress (AS) is often studied as a distinct construct, this study focuses on stress experienced in an academic setting, which encompasses both academic and non-academic stressors that students encounter during their university life [13]. This approach allows for a broader understanding of how stress in an educational environment affects students' well-being and performance. Stress in academic settings is particularly intensified before exams and is linked to increased cortisol levels, disrupted sleep homeostasis, and impaired emotional regulation [14, 15]. According to the cognitive-sleep quality model, excessive academic worries generate hyperarousal, affecting the perception of sleep duration and efficiency [9]. Similarly, from the perspective of the transactional stress model, stress arises from the interaction between perceived demands and personal resources, potentially resulting in burnout, cognitive fatigue, and impaired academic performance [16]. However, unlike studies that focus exclusively on academic stress as a construct, this study examines stress in a broader academic context, considering both academic and non-academic factors that contribute to students' stress levels.

University students must autonomously manage academic, social, and personal responsibilities, a challenge that is exacerbated by limited institutional support, increasing stress and reducing the ability to balance competing demands effectively [17]. As the semester progresses, sustained cognitive overload and accumulated stressors lead to chronic hypothalamic-pituitary-adrenal (HPA) axis activation, with prolonged cortisol secretion contributing to neuroimmune alterations and autonomic dysregulation [18]. Chronic stress induces dysregulation of the autonomic nervous system, characterized by a shift toward sympathetic dominance and a reduction in vagal tone, increasing vulnerability to cardiovascular and neurological disorders [19, 20]. Among university students, chronic stress is frequently associated with insufficient sleep, unhealthy dietary habits, reduced physical activity, increased resting heart rate, and alterations in cardiac autonomic balance [21]. On an emotional level, stress in academic settings contributes to anxiety, emotional detachment, irritability, and a diminished sense of self-efficacy, which in turn impact cognitive functions such as sustained attention, working memory, and problem-solving abilities [22, 23].

Despite the growing body of research on stress in educational settings, there is a lack of integration between psychological, physiological, and academic outcomes. Existing studies have largely focused on isolated aspects, such as the effects of stress on academic performance or the role of sleep in psychological well-being, without considering their interplay [24-26]. Furthermore, physiological markers like heart rate variability, which offer valuable insights into the autonomic nervous system's response to stress, remain underexplored in the context of academic settings. This fragmentation limits our understanding of how these factors evolve over time and are associated with each other. Addressing this gap is essential to develop evidence-based strategies for promoting resilience and academic success among university students.

The primary objective of this study was to analyze the longitudinal effects of stress in an academic context on key psychological, physiological, and behavioral variables in university students. Specifically, we examined how increasing stress in academic settings throughout the semester was associated with sleep quality, psychological flexibility, anxiety, depressive symptoms, physical activity, heart rate variability, and academic performance. This study aimed to provide a global perspective on how stress related to academic demands affects students' mental and physical health, identifying complex associations between psychological well-being and academic performance. We hypothesized that higher levels of stress over the semester would negatively affect sleep quality, psychological flexibility, and heart rate variability while leading to higher levels of anxiety and depressive symptoms. Despite these negative psychological and physiological effects, we expected to observe a moderate improvement in academic performance, suggesting that students prioritize their studies at the expense of their well-being. The results of this research would provide a holistic understanding of the effect of stress in an academic environment, offering actionable insights for educational institutions to support student well-being better and optimize academic outcomes.

Methods

Participants

In the current study, 115 volunteer Colombian university students enrolled in a psychology program, aged between 16 and 35 years (M = 19.7, SD = 3.32), were assessed through an online questionnaire at two points: the beginning (February 2024) and the end (May 2024) of the academic semester. The sample was predominantly female, comprising 79.13% of participants. A non-probabilistic criterion-based sampling method was employed to select participants. The sample size (N = 115) was established based on previous research investigating stress in academic settings and physiological responses in university students, which utilized similar sample sizes to identify significant effects [27]. Participants were selected based on specific inclusion and exclusion criteria to ensure sample homogeneity and minimize potential confounding factors. The inclusion criteria required students to be actively enrolled in the psychology program at the university, reside in Colombia during the study period, be between 16 and 35 years old, and voluntarily provide informed consent. The exclusion criteria included having a diagnosed medical or psychiatric condition that could affect stress responses, sleep patterns, or physiological measurements; taking medications such as psychotropics or beta-blockers that could interfere with autonomic or cardiovascular function; engaging in high-performance sports or extreme training routines that could significantly alter physiological markers such as HRV; and failing to complete both study assessments at the beginning and end of the semester. To ensure data integrity and prevent duplicate responses, students provided their university ID, which was cross-checked with institutional records. Participation was entirely voluntary, and all students digitally signed an informed consent form outlining the study's objectives and procedures. The study complied with the ethical guidelines of the Helsinki Declaration on Human Research and was approved by the University Ethics Committee (CIPI/2024(611)).

Procedure

To achieve the objectives of this study, a longitudinal design was implemented with two measurement points: at the beginning and at the end of the academic semester (four months later). Data collection was conducted in person on campus and comprised three main components: online self-administered questionnaires, standardized assessments of academic performance, and measures of heart rate variability (HRV), all performed in a supervised classroom setting. Participants accessed the questionnaire using their personal electronic devices, such as laptops, tablets, or smartphones. Prior to the assessments, a trained researcher provided standardized verbal instructions and remained available to clarify any questions, ensuring that responses remained unbiased. To further minimize response bias, several measures were implemented: all participants received uniform instructions, the survey was self-administered to limit interviewer bias, and a controlled classroom environment was maintained to ensure consistency in assessment conditions (See Fig. 1).

Academic performance was assessed using a standardized test, scored on a scale from 1 to 5 (1 = low, 5 = high). This test was administered at three points during the semester and consisted of 16 multiple-choice questions with a single correct answer. The initial score corresponded to the first evaluation conducted at the beginning of the academic period, and not to grades from previous semesters. The format and difficulty level of the exam remained constant in all administrations, which ensured comparability of scores over time; on the other

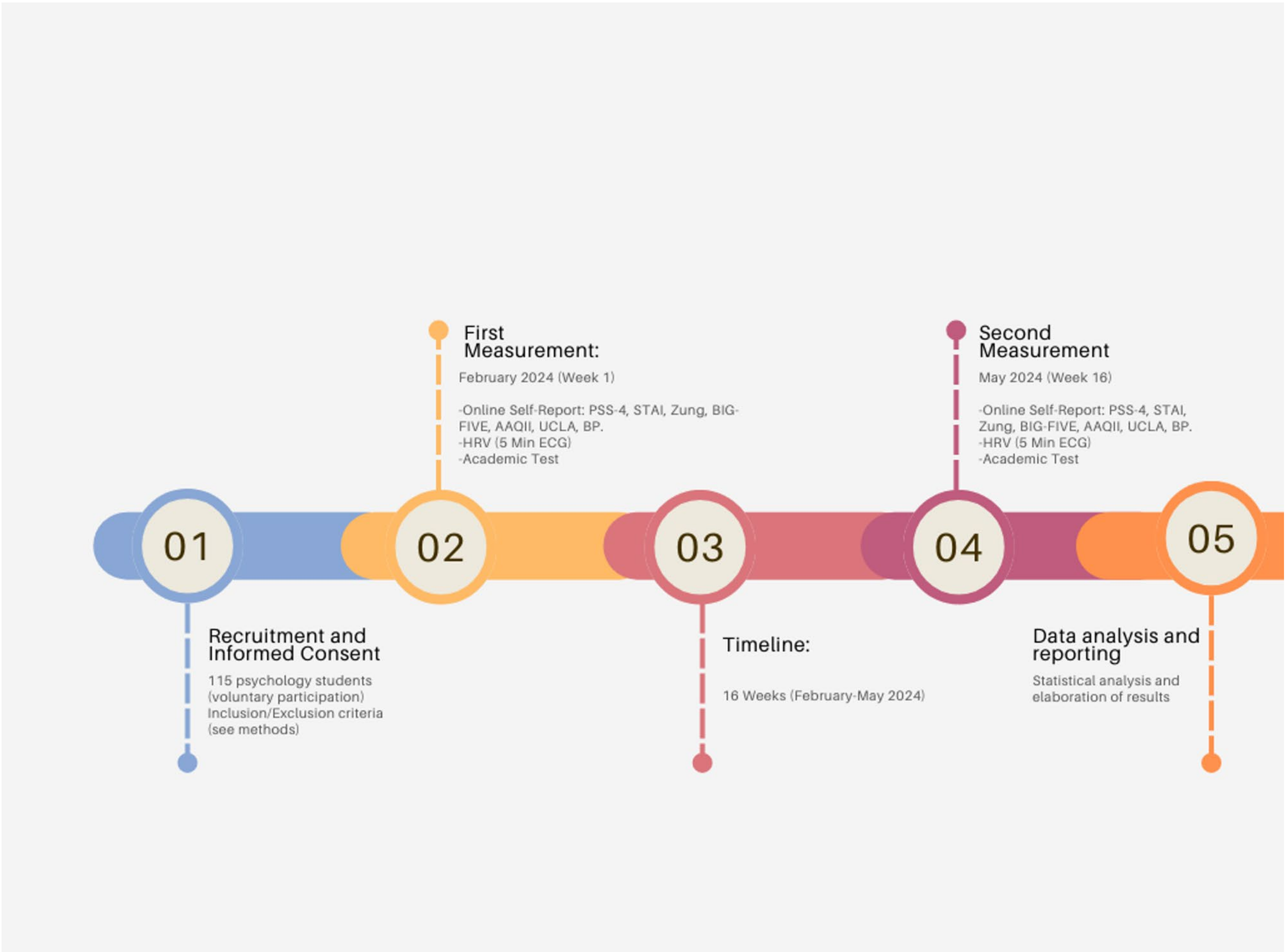

Fig. 1 Study Phases
Note: PSS-4: Perceived Stress Scale; STAI: State-Trait Anxiety Inventory; Zung: Depression Scale; BIG-FIVE: Big Five Inventory; AAQII: Acceptance and Action Questionnaire II; UCLA: Loneliness Scale; BP: Behavioral patterns (Sleep, Physical activity)

hand, the content of the test varied according to the progression of the curriculum. This avoided the repetition of content and the learning effect. The evaluation was not blinded, as it was part of the regular academic assessment process conducted by instructors. However, since it was a pre-established standardized test, its objectivity and consistency were maintained throughout the study.

A shortened version of the Spanish adaptation of the Big Five Inventory was utilized to assess personality traits, focusing on characteristics such as openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. This abbreviated version comprises 10 items rated on a 5-point Likert scale, where 1 represents strong disagreement and 5 indicates strong agreement [28]. The scale showed good reliability, achieving a Cronbach's α of 0.70, except for the openness to experience factor, which had a value of 0.65 [29]. Trait scores were calculated by summing responses to relevant items, yielding ranges of 2–10 points (2 items × 1–5 Likert scale). Grouped participants into quartiles (Q1–Q4) based on sample distribution. Quartile cutoffs were: Q1 ≤ 3.0; Q2 = 4–5; Q3 = 6–7; Q4 ≥ 8. These personality traits were included in the study due to their potential influence on stress responses, coping mechanisms, and academic performance. Additionally, the Spanish version of the Zung Depression Scale was employed to evaluate the severity of depressive symptoms as perceived by the individual [30]. This scale demonstrated strong reliability, with a Cronbach's α of 0.85 [31]. Regarding its interpretation, scores ranging from 20 to 49 indicate no or low depression, 50 to 69 indicate moderate depression, and 70 to 80 suggest severe depression. Furthermore, the Spanish version of the UCLA Loneliness Scale was utilized to measure loneliness. This scale assesses perceived loneliness, which refers to the subjective feeling of isolation or social disconnection that an individual may experience; higher scores reflect greater levels of perceived loneliness. In this study, we utilized a condensed version consisting of three items, rated on a three-point

Likert scale, where 1 signifies "never" and 3 signifies "frequently." The reliability of this test varied between 0.89 and 0.94 [32].

To assess anxiety, a condensed version of the Spanish adaptation of the Spielberger State-Trait Anxiety Inventory was utilized [33], comprising 6 items that measure anxiety on a 4-point Likert scale, where 1 signifies "not at all" and 4 signifies "very much." A score exceeding 19 points indicates significant symptoms of state anxiety. The reliability of this test ranges from 0.85 to 0.93 [34-36]. Additionally, the Spanish version of the Acceptance and Action Questionnaire II was employed to evaluate experiential avoidance or psychological inflexibility through 7 items rated on a 7-point Likert scale, with 0 denoting "never true" and 7 denoting "always true." Typically, average scores for participants without clinical issues fall between 18 and 23 points, while scores for clinical participants are generally above 29 points, indicating that higher scores are linked to greater psychological inflexibility. The reliability of this test is measured at 0.84 [37]. The PSS-4, adapted by Herrero and Meneses, was employed to assess perceived stress. This 4-item scale measures how frequently individuals experience stress, with higher scores reflecting greater perceived stress levels. While Herrero and Meneses utilized a scale ranging from 1 to 5, this study applied Cohen's original 0 to 4 scale, where 0 indicates "never" and 4 signifies "very often." The scale demonstrated solid reliability, achieving a Cronbach's α of 0.72, and accounted for 54% of the variance [38].

Behavioral patterns of participants were evaluated in line with previous studies [39-41]. Sleep duration was assessed using a self-reported measure, where students indicated the number of hours they typically sleep per night. Sleep quality was evaluated with a Likert scale from 1 (very poor quality) to 10 (very good quality), capturing participants' subjective perception of their most recent sleep episode. While validated instruments such as the Pittsburgh Sleep Quality Index (PSQI) provide a more detailed assessment, a single-item scale was chosen for its feasibility in a longitudinal study and to reduce participant burden. Physical activity was assessed through self-reported measures adapted from previous research [42, 43]. To estimate their average daily steps, students were instructed to check the step count recorded on their mobile phones or wearable devices (e.g., smartwatches, fitness bands) and report the weekly average. This approach ensured that the data reflected actual recorded movement rather than subjective estimation. However, as step counts were not collected using standardized research-grade accelerometers, results should be interpreted with caution. Also, the questionnaire included the following items: 'Did you do any physical activity in the last 7 days?', 'If so, indicate the total time (in minutes) spent on cyclic and/or aerobic activities (cycling, treadmill, Zumba) over the past week,' and 'If so, indicate the total time (in minutes) spent on resistance activities (sit-ups, push-ups, squats, or weight training) over the past week.' Although validated tools such as the Global Physical Activity Questionnaire (GPAQ) offer a standardized approach to measuring physical activity, we prioritized a brief self-report method that allowed us to track changes in activity levels over time while maintaining a manageable survey length. This approach aligns with prior studies evaluating physical activity patterns in university students.

Autonomic modulation was assessed through heart rate variability (HRV) analysis. HRV data were collected using the EEG for Everybody mobile device (NoviSad, Serbia), following previously established procedures [44, 45]. Participants remained seated in a quiet room during the recordings to minimize movement and external interferences. A 5-minute segment of continuous electrocardiographic (ECG) data was analyzed, as recommended for short-term HRV assessment. The following HRV parameters were extracted: heart rate (HR), rMSSD (square root of the mean squared differences between successive R–R intervals), PNN50 (percentage of R–R intervals differing by more than 50 ms), standard deviation 1 (SD1), standard deviation 2 (SD2), SD1/SD2 ratio, low frequency (LF), high frequency (HF), LF/HF ratio, low frequency in normalized units (LFnu), and high frequency in normalized units (HFnu).

The assessments took place during the first term of the academic semester. The measurement instruments employed in this study have been thoroughly validated within Spanish-speaking populations and have exhibited strong psychometric properties. Prior to data collection, a pilot test was administered to a small group of students to assess the clarity of the questionnaire items. No significant comprehension challenges were reported, affirming that the chosen instruments were well-suited for the target population.

Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 24.0 (SPSS Inc., Chicago, IL., USA). Descriptive statistics, including means and standard deviations, were calculated for all variables. Prior to conducting parametric tests, the assumptions of normality and homogeneity of variances were assessed. Normality was evaluated using the Kolmogorov-Smirnov test, which indicated that the data for all variables followed a normal distribution ($p > 0.05$). Homogeneity of variances was confirmed using Levene's test ($p > 0.05$). To address potential outliers, we conducted a boxplot analysis and applied the interquartile range (IQR) method. Data points falling below Q1–1.5*IQR or* *above Q3 + 1.5*IQR were considered outliers and transformed to reduce their influence on the results. Missing data were handled using listwise deletion, as the percentage of missing values was less than 5% and assumed to be missing completely at random. To examine differences between the first and second measurements across biomedical, psychological, psychophysiological, and academic variables, paired samples *t*-tests were conducted. To control Type I error inflation from multiple testing, we applied the Holm-Bonferroni sequential correction method, adjusting significance thresholds for each comparison based on its rank order ($\alpha adj = 0.05/[k - i + 1]$, where i = rank of the p-value). Effect sizes were calculated using Cohen's *d* [46], with the following classification: negligible effect (≥ -0.15 and < 0.15), small effect (≥ 0.15 and < 0.40), medium effect (≥ 0.40 and < 0.75), large effect (≥ 0.75 and < 1.10), very large effect (≥ 1.10 and < 1.45), and huge effect (≥ 1.45). Two multiple linear regression models were conducted to assess the associations of various predictors with academic performance. The first model examined the association of study variables on academic performance, while the second model evaluated whether these relationships remained consistent over time, using only the second assessment measurements. Sex and age were included as confounding variables in both models. Collinearity was assessed using the variance inflation factor (VIF), with all variables yielding VIF values below 10, indicating no multicollinearity issues. The significance level was set at $p \le 0.05$ for all analyses.

Results

The findings of this study support the initial hypotheses, indicating that heightened stress within an academic environment throughout the semester led to a reduction in sleep hours, accompanied by an increase in anxiety and depressive symptoms. Additionally, although the changes were not statistically significant, effects on heart rate variability were observed (as indicated by effect sizes). Despite these negative consequences, students demonstrated improvements in their academic performance, suggesting that they may have prioritized their studies at the expense of their overall well-being (see Fig. 2).

Table 1 presents longitudinal changes in sleep duration and quality. Students reported sleeping fewer hours at the end of the semester (M: 6.37; SD: 1.29) compared to baseline (M: 6.78; SD: 1.24), with a statistically significant difference after Holm-Bonferroni correction (t (115) = 3.68, $p < 0.02$, d = 0.32). Sleep quality also declined (M = 5.33, SD = 2.11 vs. M = 5.92, SD = 2.14), though this difference was not significant after correction (t (115) = 2.60, $p < 0.21$, d = 0.28). These findings support the hypothesis that stress in an academic context contributes to deteriorating sleep patterns. However, it is important to acknowledge that other external factors, such as work commitments or family responsibilities, may also contribute to these changes in sleep patterns.

Similarly, anxiety levels, assessed with the STAI questionnaire, showed a significant increase (M: 13.50; SD: 4.35 at follow-up vs. M: 12.17; SD: 3.93 at baseline), (t (115) = -3.53, $p < 0.04$, d = 0.32), reinforcing the idea that accumulating academic demands elevate stress responses. Depressive symptoms (ZUNG scale) increased significantly (M: 45.69; SD: 5.68 at baseline vs. M: 48.77; SD: 7.11 at follow-up), (t (115) =-4.65, $p < 0.01$, d = 0.48). This increase in depressive symptoms may be linked to high academic demands, accumulated stress, and a potential decline in activities promoting emotional well-being. In contrast, psychological inflexibility decreased (M: 27.55; SD: 9.75 at baseline vs. M: 25.38; SD: 11.23 at follow-up), but this change was not significant (t (115) = 2.52, $p < 0.21$, d = 0.21); however, it may be an indicator of better adaptability to cognitive and emotional challenges over time. Regarding personality traits (Big Five) showed no significant changes over time (all $p > 0.05$).

Concerning physical activity, no significant changes were observed in overall movement levels; however, a non-significant trend (small effect size) suggested reduction in weight training and abdominal exercises was detected at the end of the semester (M: 403.85; SD: 363.33 at baseline vs. M: 255.38; SD: 172.90 at follow-up), t [13] = 2.12, $p < 0.35$, d = 0.38. This suggests that while students may have maintained general movement (e.g., walking or low-intensity activities), they engaged less in structured strength or resistance training.

Indicators of heart rate variability (HRV) showed non-significant but meaningful effect sizes, which could contribute to the hypothesis that increased stress could be associated with autonomic dysregulation. A decrease was observed in PNN50 (M: 29.50; SD: 22.14 at baseline vs. M: 24.40; SD: 17.45 at follow-up), t (114) = 2.18, $p < 0.21$, d = 0.25, and SD1 (M: 34.53; SD: 19.37 at baseline vs. M: 30.42; SD: 13.96 at follow-up), t (113) = 2.00, $p < 0.28$, d = 0.24, indicating a reduced ability to autonomically regulate heart rate. Conversely, an increase in Hfnu was noted (M: 40.08; SD: 21.33 at baseline vs. M: 46.06; SD: 21.11 at follow-up), t (114)=-2.25, $p < 0.14$, d = 0.28, suggesting an overactivation of parasympathetic activity as a potential compensatory mechanism for stress-induced physiological changes. These findings highlight that prolonged stress in an academic context can be associated with physiological exhaustion, increasing susceptibility to long-term health risks. On the other hand, despite the psychological and physiological toll, academic performance improved significantly. Final grades (M: 4.07; SD: 0.77) were higher than initial ones (M: 3.77; SD: 0.61), t (110) = -3.41, $p < 0.02$, d = 0.43.

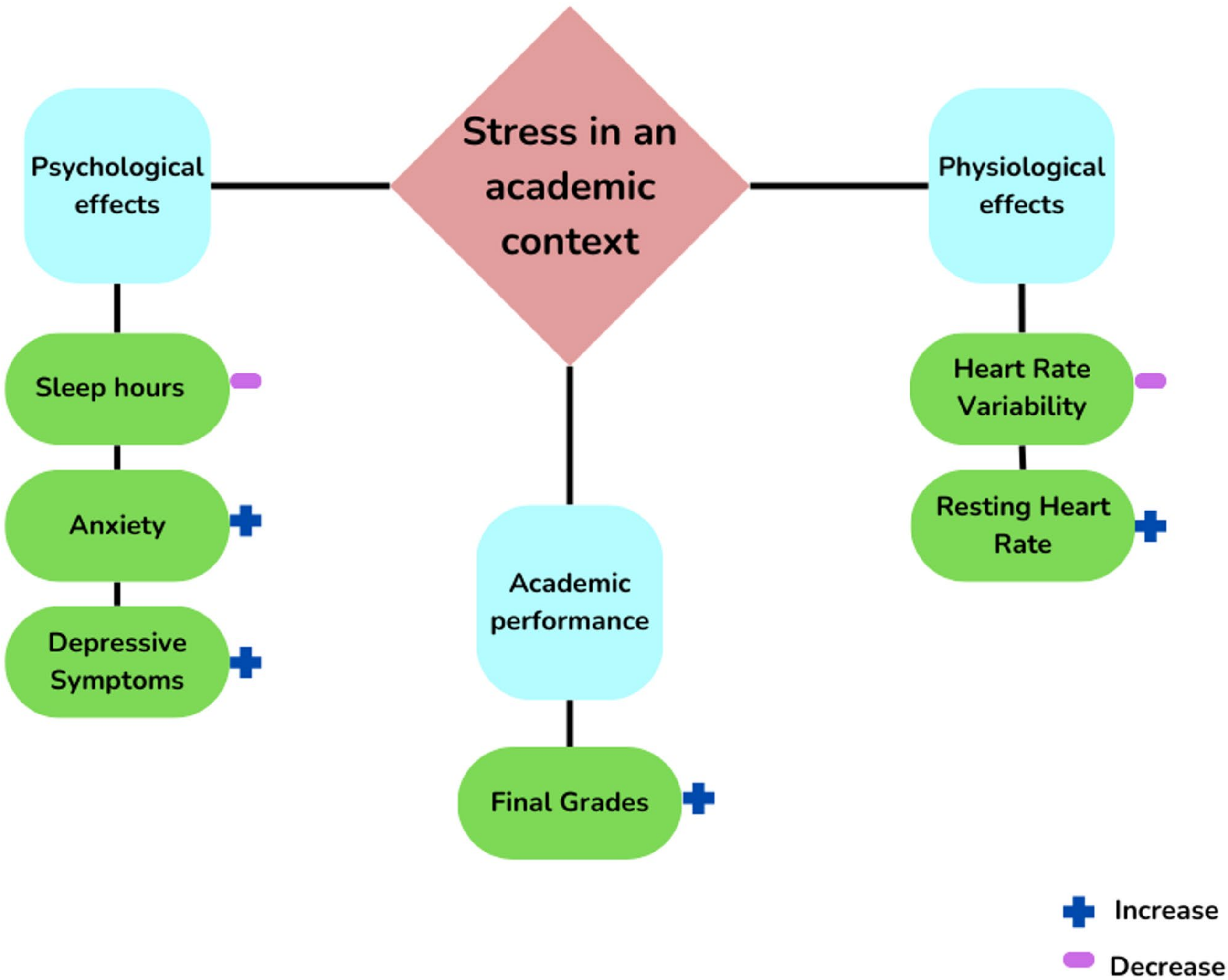

Fig. 2 Effects of Stress on academic context on University Students: A Conceptual Overview

To examine the relationships between variables in more detail, two regression models were conducted (Table 2). The first model analyzed the association of psychological, physiological, and behavioral factors at the beginning of the semester on academic performance. Symptoms of depression emerged as a significant negative predictor (B = -0.03, $p = 0.01$), reinforcing the association between mental health and lower academic achievement. Conversely, greater HRV (SD1) at baseline predicted higher performance (B = 0.01, $p = 0.04$), emphasizing the role of autonomic regulation in cognitive function. This model explained 11% of the variance in academic performance and was statistically significant ($p < 0.02$).

The second model assessed whether these relationships persisted at the semester's end. Higher sleep quality was associated with slightly lower academic performance (B = -0.06, $p = 0.05$), potentially reflecting reduced study time in students who prioritized rest. This could support the second hypothesis, indicating that students enhance their performance over time, potentially at the cost of well-being. Additionally, increased resting heart rate negatively predicted academic performance (B = -0.01, $p = 0.01$), whereas greater HRV (PNN50) was positively associated with academic outcomes (B = 0.02, $p = 0.02$). Lower SD1 values correlated with poorer academic performance (B = -0.03, $p = 0.01$), reinforcing the importance of autonomic flexibility in academic success. This model accounted for 16% of the variance and was statistically significant ($p < 0.01$).

In both regression models, sex was included as a confounding variable. At the first measurement, male students obtained significantly lower academic performance scores compared to female students. This difference was no longer apparent at the second measurement, suggesting a possible adaptation to academic demands across the semester or the influence of other variables that gained relevance over time (Table 2).

Table 1 Descriptive statistics and comparison of variables by measurements

Variables		Measurements	*n*	M	SD	t-student	*P*-value	*P*-adjusted	d
Biomedical	Weight (kg)	1	113	62.61	13.89	-0.19	0.84	1.00	0.01
		2		62.69	13.27				
	Hours of sleep per day	1	115	6.78	1.24	3.68	0.01	0.02	0.32
		2		6.37	1.29				
	Quality of sleep	1	115	5.92	2.14	2.60	0.01	0.21	0.28
		2		5.33	2.11				
Personality	BIG-FIVE Extraversion	1	115	4.83	1.62	-0.50	0.61	1.00	0.06
		2		4.92	1.53				
	BIG-FIVE Agreeableness	1	115	5.91	1.50	-0.56	0.57	1.00	0.05
		2		5.99	1.41				
	BIG-FIVE Conscientiousness	1	115	6.20	1.68	0.56	0.57	1.00	0.06
		2		6.10	1.70				
	BIG-FIVE Neuroticism	1	115	6.63	1.92	-1.23	0.22	1.00	0.11
		2		6.84	1.79				
	Open to Experience	1	115	8.01	1.59	1.58	0.11	0.77	0.15
		2		7.76	1.70				
Anxiety	STAI	1	115	12.17	3.93	-3.53	0.01	0.04	0.32
		2		13.50	4.35				
Psychological Inflexibility	AQQII	1	115	27.55	9.75	2.52	0.01	0.21	0.21
		2		25.38	11.23				
Solitude	Solitude UCLA	1	115	5.32	1.89	1.74	0.84	1.00	0.15
		2		5.04	1.77				
Perceived stress	PSS-4	1	115	6.63	3.33	-1.67	0.09	0.63	0.18
		2		7.20	3.05				
Symptoms of depression	ZUNG Scale	1	115	45.69	5.68	-4.65	0.01	0.01	0.48
		2		48.77	7.11				
Physical activity	Steps	1	41	6458.12	10481.85	0.18	0.85	1.00	0.04
		2		6058.76	8502.75				
	Cyclical/aerobic activity	1	15	174.67	168.47	0.31	0.76	1.00	0.09
		2		157.20	105.85				
	Weight/abs activity	1	13	403.85	363.33	2.12	0.05	0.35	0.38
		2		255.38	172.90				
Heart rate variability	HR	1	114	83.82	15.38	-1.88	0.06	0.42	0.21
		2		86.99	14.32				
	rMSSD	1	114	48.02	23.53	1.89	0.06	0.42	0.23
		2		43.04	19.62				
	PNN50	1	114	29.50	22.14	2.18	0.03	0.21	0.25
		2		24.40	17.45				
	SD1	1	113	34.53	19.37	2.00	0.04	0.28	0.24
		2		30.42	13.96				
	SD2	1	114	48.14	26.26	0.76	0.44	1.00	0.09
		2		45.98	21.57				
	LFNU	1	114	57.56	22.13	1.49	0.13	0.77	0.19
		2		53.38	21.97				
	Hfnu	1	114	40.08	21.33	-2.25	0.02	0.14	0.28
		2		46.06	21.11				
Academic performance	Evaluation grade	1	110	3.77	0.61	-3.41	0.01	0.02	0.43
		2		4.07	0.77				

Note: M: Mean; SD: Standard deviation; Measurement 1: first measurement; Measurement 2: second measurement; STAI: State anxiety questionnaire; AAQII: Acceptance and Action Questionnaire; PSS-4: Perceived Stress Scale 4; HR: Heart rate; rMSSD: square root of average sum of diff squared between normal r-r; PNN50:% of diff between normal R–R intervals greater than 50; SD1: Sensitivity of short-term variability of HRV; SD2: Long-term variability of the HRV spectrum; LFnu: Low frequency; HFnu: High frequency; Height measured in centimeters; Weight measured in kilograms; d: Cohen, effect size; P-adjuted: Holm-Bonferroni correction

Table 2 Results of the linear regression model for academic performance

Measure	Variable	B	Standar Error	Beta	t	*p*-value	IC 95% para B	VIF
First measurement	**Constant**	2.29	1.31	-	1.74	0.08	[-0.31–4.90]	-
	Age	0.01	0.01	0.01	0.05	0.95	[-0.03–0.03]	1.03
	Sex (Male)	-0.36	0.17	-0.24	-2.11	0.04	[-0.69–0.02]	1.53
	Symptoms of depression	-0.03	0.01	-0.24	-2.54	0.01	[-0.04–0.01]	1.08
	Cardiac Variability (SD1)	0.01	0.01	0.19	2.07	0.04	[0.00–0.01]	1.00
Second measurement	**Constant**	2.84	1.72	-	1.65	0.10	[-0.58–6.26]	-
	Age	0.02	0.02	0.1	1.14	0.26	[-0.02–0.07]	1.04
	Sex (Male)	0.05	0.21	0.02	0.25	0.79	[-0.36–0.47]	1.53
	Sleep quality	-0.06	0.03	-0.18	-1.97	0.05	[-0.13–0.01]	1.10
	Cardiac Variability (HR)	-0.01	0.01	-0.25	-2.6	0.01	[-0.02–0.01]	1.16
	Cardiac Variability (PNN50)	0.02	0.01	0.51	2.22	0.02	[0.01–0.04]	6.65
	Cardiac Variability (SD1)	-0.03	0.01	-0.63	-2.65	0.01	[-0.06–0.01]	6.89

Note: Dependent variable: Evaluation grade. The variables, age and sex, were included in the model, as they were considered confounding variables. Sex coded as 0 = female, 1 = male. At first measurement, male students showed significantly lower performance compared to females (B = -0.36, $p = 0.04$). No significant difference was found at the second measurement. Symptoms of depression: Zung Scale; SD1: Sensitivity of short-term variability of HRV; HR: Heart rate; PNN50:% of diff between normal R–R intervals greater than 50; VIF: Variance Inflation Factor

Discussion

This study investigated the longitudinal effects of stress in an academic context on psychological, physiological, and behavioral variables, including sleep quality, psychological flexibility, anxiety, depressive symptoms, physical activity, heart rate variability, and academic performance in college students over one semester. The results partially confirm the initial hypotheses, revealing that higher levels of stress over the semester negatively affected sleep quality and heart rate variability, while leading to higher levels of anxiety and depressive symptoms, as hypothesized. Interestingly, despite the adverse psychological and physiological effects, academic performance improved significantly, supporting the hypothesis that students prioritize their studies at the expense of their well-being.

From a physiological perspective, this study provides important insights into the relationship between stress markers and academic performance in university students. The observed decline in sleep quantity and quality over time aligns with the hypothesis that stress in academic settings would negatively affect sleep, consistent with previous research showing that students often sacrifice rest to meet academic demands [47, 48]. However, an unexpected finding emerged: improvements in sleep quality were associated with a slight decrease in academic achievement. This contrasts with the well-established link between better sleep and enhanced cognitive functions, such as memory and attention [49]. Several factors may explain this counterintuitive result. First, it could reflect specific behaviors in our sample, such as nighttime study habits that prioritize academic preparation over sleep, a phenomenon supported by studies showing no significant differences in academic performance between students at risk for sleep disorders and those without sleep disorders [50]. Second, the use of self-reported sleep data introduces potential biases, such as inaccuracies in perceived sleep quality or higher-performing students reporting greater dissatisfaction due to increased academic pressures [51, 52]. These findings align with recent research on the interplay between stress, health behaviors, and academic performance. For example, one study found that positive thinking, good sleep quality, and higher physical activity levels were associated with improved well-being and/or better performance during high-stakes assessments, such as objective structured clinical examinations (OSCEs) [53]. In contrast, avoidance coping strategies negatively affected both well-being and performance, supporting our observation that students may prioritize academic demands over sleep, potentially adopting maladaptive coping strategies that compromise their well-being.

Interestingly, perceived stress levels, as measured by the PSS-4, did not exhibit a statistically significant change throughout the semester. This stability in perceived stress may suggest that students maintained a consistent perception of their stress levels, possibly due to habituation to academic demands or stable baseline stressors unrelated to academic context. It is also possible that while objective markers (e.g., HRV, sleep) and emotional symptoms (e.g., anxiety, depression) fluctuated, students' subjective appraisal of their stress remained unchanged, highlighting a potential disconnect between perceived and physiological stress responses [7, 26, 54]. This finding aligns with research suggesting that self-reported stress can sometimes remain stable despite underlying changes in emotional or physiological states [55, 56].

Regarding heart rate variability (HRV), the results support the hypothesis that stress may be associated with autonomic dysregulation. At the beginning of the semester, a higher HRV, specifically in the SD1 component (reflecting parasympathetic activity and autonomic recovery), predicted better academic performance.

This finding suggests that students with greater autonomic regulation at the start of the semester were better equipped to handle academic demands, highlighting the crucial role of physiological homeostasis in cognitive function [57]. For instance, higher parasympathetic activity has been linked to greater cognitive flexibility and stress management, which may facilitate more effective academic performance [58]. However, as the semester progressed, the relationship between physiological markers and academic outcomes shifted. Reductions in PNN50 and SD1, along with increases in Hfnu, indicated a diminished autonomic capacity to regulate stress, aligning with existing literature linking chronic stress to autonomic dysfunction [59-63]. Low HRV has been established as a key physiological marker of prolonged stress, reflecting its impact on emotional regulation and cognitive performance [64].

Further analysis revealed that resting HR at the end of the semester was inversely associated with academic performance, suggesting that sustained physiological activation may undermine students' ability to manage academic demands effectively [60, 61]. In addition, the positive association between PNN50 at the end of the semester and academic performance further underscores the importance of parasympathetic activity in maintaining cognitive and emotional resilience. PNN50, which reflects the proportion of successive RR intervals that differ by more than 50 milliseconds, is a marker of vagal tone and autonomic recovery. Higher PNN50 values indicate greater parasympathetic activity, which has been associated with better stress management, enhanced attention, and improved cognitive performance [65, 66]. This finding suggests that students with greater autonomic flexibility and recovery capacity are better equipped to handle academic challenges, supporting the idea that physiological resilience plays a key role in academic success.

These results highlight the dual risks of insufficient physiological arousal and excessive physiological overload, both of which can compromise academic performance. This aligns with previous research showing that moderate autonomic activation is optimal for cognitive functioning, while extreme imbalances, whether due to elevated stress or excessive relaxation, are detrimental to both performance and well-being [67, 68]. The initial protective effect of higher HRV (SD1) at the start of the semester may diminish as academic demands increase, suggesting that chronic stress and fatigue could alter the relationship between autonomic regulation and academic outcomes over time. Despite the adverse effects of chronic stress on physiological well-being, students suggest an improvement in final grades, which may suggest a compensatory mechanism wherein academic performance is prioritized over physical and emotional health, supporting our study hypothesis. This complex association, previously documented in stress studies [69, 70], raises significant concerns, as it underscores the hidden costs of academic success, particularly the neglect of students' overall well-being; however, unmeasured factors (e.g., study habits) could contribute to this association.

Regarding the connection between psychological indicators of mental health and academic performance, psychological flexibility defined as the ability to manage and respond adaptively to emotional and psychological stressors showed a positive trend throughout the semester, although it was not statistically significant. This finding contrasts with the study's initial hypothesis, which predicted that students would experience a decline in psychological flexibility due to the cumulative effects of academic stress. Instead, the results suggest that students developed a greater capacity to adapt to emotional challenges under sustained stress, a finding consistent with research highlighting the role of psychological flexibility as a protective factor in high-demand environments [71, 72]. For instance, studies have shown that individuals with higher psychological flexibility are better equipped to handle academic pressures and maintain emotional well-being, even in the face of significant stressors [73, 74]. However, despite this improvement in psychological flexibility, students experienced an increase in symptoms of depression and anxiety by the end of the semester, which is consistent with the study's hypotheses. This contrasts with some studies that have found psychological flexibility to be inversely associated with symptoms of depression and anxiety [75]. The discrepancy may be explained by the unique nature of stress in an academic context, which often involves prolonged exposure to high demands and limited recovery time, potentially overwhelming even adaptive coping mechanisms [76]. Conversely, students exhibiting heightened depressive symptoms at the outset of the semester were more likely to experience diminished academic performance, underscoring the lasting impact of mental health on academic outcomes [77]. Although the reported symptoms did not reach clinically significant thresholds, they indicate a discernible psychological decline linked to stress in academic environments [78]. This finding aligns with research suggesting that stress can precipitate subclinical levels of mental health issues, which, despite not fulfilling diagnostic criteria, can still adversely affect well-being and academic achievement [13].

While previous research has shown that personality traits influence stress vulnerability and coping effectiveness [79, 80], our findings did not reveal this. Specifically, none of the personality traits included in our regression models were statistically significant predictors of academic performance. This contrasts with studies suggesting that traits such as neuroticism, extraversion, and conscientiousness play a key role in stress responses and academic outcomes [79, 80]. The lack of significant findings in our study may be attributed to several factors, such as the homogeneity of personality traits in our sample or the predominance of contextual factors (e.g., academic workload, institutional support) that overshadowed the relation of personality.

This study highlights the intricate interplay between psychological, physiological, and behavioral factors in predicting academic performance, including variables such as sleep quality, perceived stress, psychological flexibility, and heart rate variability. Academic success appears to emerge from a complex interplay between physiological arousal (stress) and the psychological flexibility to manage it effectively. In academic settings, stress often functions as a positive determinant of performance under specific conditions, which partially coincides with eustress theory, which posits that moderate levels of stress can act as a motivating force that enhances performance [81, 82]. Professional studies present environments that simultaneously generate both beneficial and detrimental forms of stress, offering opportunities for students to develop skills to manage these demands. This underscores the dual nature of stress in higher education, where it can act as both a catalyst for performance and a potential detriment to overall well-being if not properly regulated. Similarly, this study emphasizes the importance of targeted interventions to mitigate the negative effects of stress in academic settings on student well-being. While students may develop adaptive mechanisms, such as increased psychological flexibility, increased symptoms of depression and anxiety illustrate the limitations of these innate coping strategies. Medical students should be offered the opportunity to participate in structured stress management programs that emphasize personalized support and goal setting, as these may help reduce psychological and physiological stress and improve students' coping abilities [83].

The limitations of this study underscore several important areas for consideration. Firstly, the sample was restricted to university psychology students from a single institution and employed a non-probabilistic sampling method, constraining the generalizability and applicability of the findings to other populations, disciplines, or educational settings. However, the physiological and behavioral markers studied (e.g., HRV, sleep) are broadly relevant to stress research in higher education. In addition, as this was an observational study, unmeasured confounding factors may influence the observed relationship, Likewise, the study results do not imply causality between the variables. Furthermore, the data collected was not anonymous, potentially influencing participants' responses due to concerns about privacy or social desirability bias. Secondly, the study relied on self-reported measures for key variables, such as perceived stress, anxiety, and sleep quality, which are vulnerable to inaccuracies stemming from recall bias, social desirability bias, and individual differences in perception. For instance, students experiencing high stress may overestimate sleep disturbances, while others might underreport them due to the normalization of poor sleep habits. These limitations emphasize the necessity for future research to supplement self-reported data with objective measures, such as actigraphy or polysomnography, to achieve a more comprehensive understanding of the relationship between sleep quality and academic performance. Third, although the study evaluated physical activity levels through self-reported measures, it did not specifically assess sedentary behavior. Future research could benefit from incorporating objective or validated self-report tools to measure sedentary time and explore its potential interaction with stress within an academic context, as well as its impact on student well-being. Additionally, although we controlled learning effects by varying test content, we cannot rule out that general test-taking skills improved over time. Future studies could include parallel test versions to address this. Furthermore, it is important to highlight that this study concentrated on stress in academic settings rather than characterizing academic stress as a distinct construct. While this perspective allowed for a broader understanding of the stressors that students encounter in their academic environments, it may have encompassed factors beyond purely academic demands, such as personal or social stressors. This broader lens might limit the direct comparability of our findings with studies that focus specifically on academic stress as a construct. However, it offers a more comprehensive view of the overall stress experience for university students, which is invaluable for developing holistic interventions. Despite these limitations, the study's findings possess considerable value and practical implications. The insights gained may guide intervention strategies for managing stress among university students, establishing a crucial foundation for future policies related to student welfare and psychological support programs. By focusing on a specific group, the research provides a more nuanced understanding of stress within that academic context, serving as a launching pad for broader comparative studies.

For future research, it would be beneficial to broaden the participant base to encompass a diverse range of institutions and demographics, allowing for the examination of whether similar results emerge across different educational scenarios. Additionally, future studies should explore specific academic stressors (e.g., exams, deadlines, workload) in a more structured manner to better understand their unique impact on student well-being and performance. This could involve developing targeted assessments or interventions that address these stressors directly. Integrating more objective stress measurement methods, such as analyzing physiological biomarkers or employing neuroimaging techniques, could enhance the study's rigor. Furthermore, investigating targeted interventions designed to alleviate stress in an academic context, with an assessment of their effectiveness through experimental or longitudinal approaches, could greatly contribute to understanding and improving student experiences throughout their academic journeys [83]. Future research should also explore the interplay between personality traits and stress in academic contexts in diverse populations and contexts to better understand their role in student well-being and performance.

The findings of this study underscore the importance of implementing comprehensive strategies to support university students' well-being during periods of heightened stress in an academic context. Educational institutions should consider integrating stress management programs, such as mindfulness training or resilience-building workshops, to mitigate the adverse psychological and physiological effects of stress [83]. Additionally, promoting better sleep hygiene and encouraging regular physical activity could enhance students' capacity to cope with academic demands [84, 85]. Leveraging tools like heart rate variability monitoring can provide personalized feedback to identify students at risk of chronic stress and tailor interventions accordingly. These approaches not only aim to improve academic performance but also prioritize the overall health and sustainability of students' educational journeys.

Conclusion

This study provides a comprehensive analysis of the long-term effects of stress within an academic context on the psychological, physiological, and behavioral outcomes of college students. The findings indicate that academic-related stress is linked to poorer sleep quality, autonomic regulation, and mental health. Notably, while there is an improvement in academic performance, this enhancement is also linked to increased anxiety, depressive symptoms, and physiological dysregulation, highlighting an often-overlooked connection between academic success and student well-being. These results emphasize the need for targeted interventions that address both academic and non-academic stressors, foster physiological resilience, and support holistic well-being. Future research should explore specific academic stressors, utilize objective measures, and evaluate the effectiveness of interventions designed to help students manage stress and achieve sustainable academic success.

Abbreviations

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Acknowledgements

Not applicable.

Author contributions

JCBA conceptualized the study, designed the methodology and directed data collection. DR participated in instrument validation and statistical analysis. ENJ reviewed the statistical analysis and made corrections to the final versions of the document. VCJCS reviewed the relevant literature and contributed to writing the introduction and discussion sections. All authors actively participated in the interpretation of the results and drafting of the manuscript. They also reviewed and approved the final version of the article.JCBA: Juan Camilo Benitez AgudeloDR: Dayana Restrepo ENJ: Eduardo Navarro Jimenez VCJCS: Vicente Javier Clemente Suarez.

Funding

The authors declare that they did not receive support from any organization for the submitted work.

Data availability statement

The datasets generated by the survey research during the current study are available in the Dataverse repository https://osf.io/9yrxz/?view_only=5cf1448bd3d846368ebbc655431e4d5d

Declarations

Ethics approval and consent to participate

All participants digitally signed an informed consent form, which outlined the study's objectives and procedures. This research adhered to the Helsinki Declaration on Human Research and was approved by the University Ethics Committee (CIPI/2024(611)).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 12 December 2024 / Accepted: 18 June 2025
Published online: 08 July 2025

References

1. McEwen BS. Stress, adaptation, and disease: allostasis and allostatic load. Ann N Y Acad Sci. 1998;840(1):33–44.
2. Chrousos GP, Gold PW. The concepts of stress and stress system disorders: overview of physical and behavioral homeostasis. JAMA. 1992;267(9):1244–52.
3. Hermans EJ, Hendler T, Kalisch R. Building Resilience: The Stress Response as a Driving Force for Neuroplasticity and Adaptation. Biol Psychiatry [Internet]. 2025;97(4):330–8. Available from: https://doi.org/10.1016/j.biopsych.2024.10.016
4. Lazarus RS. Psychological stress in the workplace. Occupational stress. CRC; 2020. pp. 3–14.
5. Stecz P, Makara-Studzińska M, Białka S, Misiołek H. Stress responses in high-fidelity simulation among anesthesiology students. Sci Rep [Internet].

2021;11(1):17073. Available from: https://doi.org/10.1038/s41598-021-96279-7
6. Agorastos A, Chrousos GP. The neuroendocrinology of stress: the stress-related continuum of chronic disease development. Mol Psychiatry [Internet]. 2022;27(1):502–13. Available from: https://doi.org/10.1038/s41380-021-01224-9
7. Crosswell AD, Lockwood KG. Best practices for stress measurement: How to measure psychological stress in health research. Heal Psychol Open [Internet]. 2020;7(2):2055102920933072. Available from: https://doi.org/10.1177/2055102920933072
8. Forman HJ, Zhang H. Targeting oxidative stress in disease: promise and limitations of antioxidant therapy. Nat Rev Drug Discov [Internet]. 2021;20(9):689–709. Available from: https://doi.org/10.1038/s41573-021-00233-1
9. Deng J, Zhang L, Cao G, Yin H. Effects of adolescent academic stress on sleep quality: mediating effect of negative affect and moderating role of peer relationships. Curr Psychol. 2023;42(6):4381–90.
10. Walker WH, Walton JC, DeVries AC, Nelson RJ. Circadian rhythm disruption and mental health. Transl Psychiatry [Internet]. 2020;10(1):28. Available from: https://doi.org/10.1038/s41398-020-0694-0
11. Liu X, Li Y, Cao X. Bidirectional reduction effects of perceived stress and general self-efficacy among college students: a cross-lagged study. Humanit Soc Sci Commun [Internet]. 2024;11(1):271. Available from: https://doi.org/10.1057/s41599-024-02785-0
12. Alharbi HF, Abaoud AF, Almutairi M, Alzahrani NS, Almarwani AM, Alenezi A et al. Gender differences in acute and perceived stress, bullying, and academic motivation among nursing and midwifery students. BMC Nurs [Internet]. 2025;24(1):26. Available from: https://doi.org/10.1186/s12912-024-02666-6
13. Barbayannis G, Bandari M, Zheng X, Baquerizo H. Academic stress and mental Well-Being in college students: correlations. Affected Groups and. 2022;13(May):1–10.
14. Sasser J, Doane LD, Su J, Grimm KJ. Stress and diurnal cortisol among latino/a college students: A multi-risk model approach. Dev Psychopathol. 2024;36(2):719–35.
15. Kristensen SM, Larsen TMB, Urke HB, Danielsen AG, Academic, Stress. Academic Self-efficacy, and psychological distress: A moderated mediation of Within-person effects. J Youth Adolesc. 2023;52(7):1512–29.
16. Zhang W, Yan W, Jin P, Wei Y. Unveiling the impact of school organizational justice on students ' professional commitment through academic stress mediation. 2024;1–18.
17. Liu X, Zhang Y, Gao W, Cao X. Developmental trajectories of depression, anxiety, and stress among college students: a piecewise growth mixture model analysis. Humanit Soc Sci Commun. 2023;10(1):1–10.
18. Sanogo F, Ruth A, Cortessis VK, Ding L, Watanabe RM, Weigensberg MJ. Associations between perceived stress and cortisol biomarkers in predominantly Latino adolescents. Sci Rep [Internet]. 2025;15(1):11572. Available from: https://doi.org/10.1038/s41598-025-95603-9
19. Capellino S, Claus M, Watzl C. Regulation of natural killer cell activity by glucocorticoids, serotonin, dopamine, and epinephrine. Cell Mol Immunol [Internet]. 2020;17(7):705–11. Available from: https://doi.org/10.1038/s41423-020-0477-9
20. Hassamal S. Chronic stress, neuroinflammation, and depression: an overview of pathophysiological mechanisms and emerging anti-inflammatories. Front Psychiatry. 2023;14(May).
21. Redondo-Flórez L, Ramos-Campo DJ, Clemente-Suárez VJ. Relationship between physical fitness and academic performance in university students. Int J Environ Res Public Health. 2022;19(22).
22. McBride EE, Greeson JM. Mindfulness, cognitive functioning, and academic achievement in college students:the mediating role of stress. Curr Psychol [Internet]. 2023;42(13):10924–34. Available from: https://doi.org/10.1007/s12144-021-02340-z
23. Ansari S, Khan I, Iqbal N. Association of stress and emotional well-being in non-medical college students: A systematic review and meta-analysis. J Affect Disord [Internet]. 2025;368:200–23. Available from: https://www.sciencedirect.com/science/article/pii/S016503272401512X
24. Clemente-suárez VJ, Beltrán-Velasco AI, Mendoza-Castejón D, Rodriguez-Besteiro S, Lopez-Varas F, Martin-Rodríguez A. Comparative analysis of academic, behavioral, and Psychophysiological variables in male and female vocational training students. Children. 2024;11.
25. Ramos-Campo DJ, Clemente-Suárez VJ. The correlation between motor skill proficiency and academic performance in high school students. Behav Sci (Basel). 2024;14(7).
26. Sánchez-Conde P, Beltrán-Velasco AI, Clemente-Suárez VJ. Analysis of the objective and subjective stress response of students and professors in practical nursing exams and their relationship with academic performance. Int J Environ Res Public Health. 2022;19(15).
27. Jiang J, Kwok SYCL, Deng X. Effects of social mistreatment, academic alienation, and developmental challenge on university students' well-being through coping strategies: A longitudinal study. Br J Educ Psychol. 2024.
28. Rammstedt B, John OP. Measuring personality in one minute or less: A 10-item short version of the big five inventory in english and German. J Res Pers. 2007;41(1):203–12.
29. Robles-Haydar CA, Amar-Amar J, Martínez-González MB. Validation of the big five questionnaire (BFQ-C), short version, in Colombian adolescents. Salud Ment. 2022;45(1):29–34.
30. Zung WWK. A Self-Rating Depression Scale. Arch Gen Psychiatry [Internet]. 1965;12(1):63–70. Available from: https://doi.org/10.1001/archpsyc.1965.01720310065008
31. Del Águila Montoya LM, Pinedo Córdova MF, Soto Sánchez SS, Torres Dávila A, Tapullima-Mori C. Escala de depresión de zung: propiedades Psicométricas En portadores Del virus de La inmunodeficiencia humana. Rev Peru Ciencias La Salud. 2021;3(4):e358.
32. Russell DW. UCLA loneliness scale (Version 3): reliability, validity, and factor structure. J Pers Assess. 1996;66(1):20–40.
33. Van Knippenberg FCE, Duivenvoorden HJ, Bonke B, Passchier J. Shortening the state-trait anxiety inventory. J Clin Epidemiol. 1990;43(9):995–1000.
34. Castellote-Caballero Y, Carcelén-Fraile M, del Aibar-Almazán C, Rivas-Campo A, González-Martín Y. Yoga as a therapeutic approach to mental health in university students: a randomized controlled trial. Front Public Heal. 2024;12(June):1–10.
35. González-Álvarez ME, Riquelme-Aguado V, Rossettini G, Fernández-Carnero J, Villafañe JH. Exercise intervention in women with fibromyalgia and its influence on pain, psychological variables, and disability: an observational study. Life. 2025;15(1):1–14.
36. Fernández-Blázquez MA, Ávila-Villanueva M, López-Pina JA, Zea-Sevilla MA, Frades-Payo B. Psychometric properties of a new short version of the State-Trait Anxiety Inventory (STAI) for the assessment of anxiety in the elderly. Neurologia [Internet]. 2015;30(6):352–8. Available from: https://doi.org/10.1016/j.nrl.2013.12.015
37. Bond FW, Hayes SC, Baer RA, Carpenter KM, Guenole N, Orcutt HK, et al. Preliminary psychometric properties of the acceptance and action Questionnaire-II: A revised measure of psychological inflexibility and experiential avoidance. Behav Ther. 2011;42(4):676–88.
38. Herrero J, Meneses J. Short Web-based versions of the perceived stress (PSS) and center for epidemiological Studies-Depression (CESD) scales: A comparison to pencil and paper responses among internet users. Comput Hum Behav. 2006;22(5):830–46.
39. Peris-Ramos HC, Míguez MC, Rodriguez-Besteiro S, David-Fernandez S, Clemente-Suárez VJ. Gender-Based differences in psychological, nutritional, physical activity, and oral health factors associated with stress in teachers. Int J Environ Res Public Health. 2024;21(4).
40. Jiménez-Morcillo J, Ramos-Campo DJ, Rodríguez-Besteiro S, Clemente-Suárez VJ. The association of body image perceptions with behavioral and health outcomes among young adults. Nutrients. 2024;16(9):1–13.
41. Martín-Rodríguez A, Tornero-Aguilera JF, López-Pérez PJ, Clemente-Suárez VJ. Overweight and executive functions, psychological and behavioral profile of Spanish adolescents. Physiol Behav. 2022;254:113901.
42. Cancela Carral JM, Lago Ballesteros J, Ayán Pérez C, Mosquera Morono MB. Análisis de fiabilidad y validez de tres cuestionarios de autoinforme para valorar la actividad física realizada por adolescentes españoles. Gac Sanit [Internet]. 2016;30(5):333–8. Available from: https://www.sciencedirect.com/science/article/pii/S0213911116300553
43. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.
44. Regueros AC, Bustamante-Sánchez Á, Clemente-Suárez VJ. Validity of photoplethysmography mobile analysis to test the autonomic stress status of tactical athletes. Rom J Mil Med. 2023;126(4):486–91.
45. Clemente-Suárez VJ. Multidisciplinary intervention in the treatment of mixed anxiety and depression disorder. Physiol Behav. 2020;219:112858.
46. Gignac GE, Szodorai ET. Effect size guidelines for individual differences researchers. Pers Individ Dif. 2016;102:74–8.
47. Stores R, Linceviciute S, Pilkington K, Ridge D. Sleep disturbance, mental health, wellbeing and educational impact in UK university students: a mixed

methods study. J Furth High Educ [Internet]. 2023;47(8):995–1008. Available from: https://doi.org/10.1080/0309877X.2023.2209777
48. Hershner S. Sleep and academic performance: measuring the impact of sleep. Curr Opin Behav Sci [Internet]. 2020;33:51–6. Available from: https://doi.org/10.1016/j.cobeha.2019.11.009
49. Zimmerman ME, Benasi G, Hale C, Yeung LK, Cochran J, Brickman AM et al. The effects of insufficient sleep and adequate sleep on cognitive function in healthy adults. Sleep Heal [Internet]. 2024;10(2):229–36. Available from: https://www.sciencedirect.com/science/article/pii/S2352721823002930
50. Gilstrap SR, Hobson JM, Dark HE, Gloston GF, Cody SL, Goodin BR, et al. Disordered sleep and its association with academic performance and functioning. Sleep Biol Rhythms. 2023;21(1):113–23.
51. Mehta KJ. Effect of sleep and mood on academic performance—at interface of physiology, psychology, and education. Humanit Soc Sci Commun [Internet]. 2022;9(1):16. Available from: https://doi.org/10.1057/s41599-021-01031-1
52. Humphries RK, Bath DM, Burton NW. Dysfunctional beliefs, sleep hygiene and sleep quality in university students. Heal Promot J Aust. 2022;33(1):162–9.
53. Barret N, Guillaumée T, Rimmelé T, Cortet M, Mazza S, Duclos A, et al. Associations of coping and health-related behaviors with medical students' well-being and performance during objective structured clinical examination. Sci Rep. 2024;14(1):11298.
54. Epel ES, Crosswell AD, Mayer SE, Prather AA, Slavich GM, Puterman E et al. More than a feeling: A unified view of stress measurement for population science. Front Neuroendocrinol [Internet]. 2018;49:146–69. Available from: https://www.sciencedirect.com/science/article/pii/S0091302218300219
55. Campbell J, Ehlert U. Acute psychosocial stress: Does the emotional stress response correspond with physiological responses? Psychoneuroendocrinology [Internet]. 2012;37(8):1111–34. Available from: https://www.sciencedirect.com/science/article/pii/S0306453011003659
56. Becker S, Spinath B, Ditzen B, Dörfler T. Psychological stress = physiological stress? An experimental study with prospective teachers. J Psychophysiol. 2023;37(1):12–24.
57. Thayer JF, Lane RD. Claude Bernard and the heart-brain connection: further elaboration of a model of neurovisceral integration. Neurosci Biobehav Rev. 2009;33(2):81–8.
58. Almarzouki AF. Stress, working memory, and academic performance: a neuroscience perspective. Stress. 2024;27(1):2364333.
59. Pham T, Lau ZJ, Chen SHA, Makowski D. Heart rate variability in psychology: A review of Hrv indices and an analysis tutorial. Sensors. 2021;21(12):1–20.
60. McEwen BS, Sapolsky RM. Stress and cognitive function. Curr Opin Neurobiol [Internet]. 1995;5(2):205–16. Available from: https://www.sciencedirect.com/science/article/pii/095943889580028X
61. Sharififard F, Asayesh H, Hosseini MHM, Sepahvandi M. Motivation, self-efficacy, stress, and academic performance correlation with academic burnout among nursing students. J Nurs MIDWIFERY Sci. 2020;7(2):88–93.
62. Matsuura Y, Ochi G. The potential of heart rate variability monitoring for mental health assessment in top wheel gymnastics athletes: A single case design. Appl Psychophysiol Biofeedback. 2023;48(3):335–43.
63. Lampert R, Tuit K, Hong KI, Donovan T, Lee F, Sinha R. Cumulative stress and autonomic dysregulation in a community sample. Stress. 2016;19(3):269–79.
64. Kim HG, Cheon EJ, Bai DS, Lee YH, Koo BH. Stress and heart rate variability: A Meta-Analysis and review of the literature. Psychiatry Investig. 2018;15(3):235–45.
65. Nicolini P, Malfatto G, Lucchi T. Heart rate variability and cognition: A narrative systematic review of longitudinal studies. J Clin Med. 2024;13(1).
66. Arakaki X, Arechavala RJ, Choy EH, Bautista J, Bliss B, Molloy C, et al. The connection between heart rate variability (HRV), neurological health, and cognition: A literature review. Front Neurosci. 2023;17:1055445.
67. Martin K, Périard J, Rattray B, Pyne DB. Physiological Factors Which Influence Cognitive Performance in Military Personnel. Hum Factors [Internet]. 2019;62(1):93–123. Available from: https://doi.org/10.1177/0018720819841757
68. Portnova GV, Liaukovich KM, Vasilieva LN, Alshanskaia EI. Autonomic and Behavioral Indicators on Increased Cognitive Loading in Healthy Volunteers. Neurosci Behav Physiol [Internet]. 2023;53(1):92–102. Available from: https://doi.org/10.1007/s11055-023-01394-9
69. Horanicova S, Husarova D, Madarasova Geckova A, Lackova Rebicova M, Sokolova L, de Winter AF et al. Adolescents' academic performance: what helps them and what hinders them from achievement and success? Front Psychol [Internet]. 2024;Volume 15. Available from: https://www.frontiersin.org/journals/psychology/articles/https://doi.org/10.3389/fpsyg.2024.1350105
70. Cage E, Jones E, Ryan G, Hughes G, Spanner L. Student mental health and transitions into, through and out of university: student and staff perspectives. J Furth High Educ [Internet]. 2021;45(8):1076–89. Available from: https://doi.org/10.1080/0309877X.2021.1875203
71. Koppenborg KA, Garnefski N, Kraaij V, Ly V. Academic stress, mindfulness-related skills and mental health in international university students. J Am Coll Heal [Internet]. 2024;72(3):787–95. Available from: https://doi.org/10.1080/07448481.2022.2057193
72. Daşcı E, Salihoğlu K, Daşcı E. The relationship between tolerance for uncertainty and academic adjustment: the mediating role of students' psychological flexibility during COVID-19. Front Psychol. 2023;14(November):1–13.
73. Kashdan TB, Rottenberg J. Psychological flexibility as a fundamental aspect of health. Clin Psychol Rev. 2010;30(7):865–78.
74. Wersebe H, Lieb R, Meyer AH, Hofer P, Gloster AT. The link between stress, well-being, and psychological flexibility during an acceptance and commitment therapy self-help intervention. Int J Clin Health Psychol. 2018;18(1):60–8.
75. Levin ME, MacLane C, Daflos S, Seeley J, Hayes SC, Biglan A, et al. Examining psychological inflexibility as a transdiagnostic process across psychological disorders. J Context Behav Sci. 2014;3(3):155–63.
76. James KA, Stromin JI, Steenkamp N, Combrinck MI. Understanding the relationships between physiological and psychosocial stress, cortisol and cognition. Front Endocrinol (Lausanne) [Internet]. 2023;Volume 14. Available from: https://www.frontiersin.org/journals/endocrinology/articles/https://doi.org/10.3389/fendo.2023.1085950
77. Quinn DM, Canevello A, Crocker JK. Understanding the role of depressive symptoms in academic outcomes: A longitudinal study of college roommates. PLoS ONE. 2023;18(6):e0286709.
78. Gil TC, Obando D, García-Martín MB, Sandoval-Reyes J, Perfectionism. Academic stress, rumination and worry: A predictive model for anxiety and depressive symptoms in university students from Colombia. Emerg Adulthood. 2023;11(5):1091–105.
79. Schlatter S, Louisy S, Canada B, Thérond C, Duclos A, Blakeley C, et al. Personality traits affect anticipatory stress vulnerability and coping effectiveness in occupational critical care situations. Sci Rep. 2022;12(1):20965.
80. Le Saux O, Canada B, Debarnot U, Haouhache NEH, Lehot JJ, Binay M, et al. Association of personality traits with the efficacy of stress management interventions for medical students taking objective structured clinical examinations. Acad Med. 2024;99(7):784–93.
81. Zhao Y. The impact of college students' academic stress on student satisfaction from a typological perspective: A latent profile analysis based on academic Self-Efficacy and positive coping strategies for stress. Behav Sci (Basel). 2024;14(4).
82. Zavaleta JC, Alva RY, Vargas SV, Medina EF, Somoza YP, Andrade-Arenas L. Relationship between stress and academic performance: an analysis in virtual mode. Int J Adv Comput Sci Appl. 2021;12(12):823–33.
83. Métais A, Omarjee M, Valero B, Gleich A, Mekki A, Henry A, et al. Determining the influence of an intervention of stress management on medical students' levels of Psychophysiological stress: the protocol of the PROMESS-Stress clinical trial. BMC Med Educ. 2025;25(1):225.
84. Ruet A, Ndiki Mayi EF, Métais A, Valero B, Henry A, Duclos A, et al. Determining the influence of a sleep improvement intervention on medical students' sleep and fatigue: protocol of the PROMESS-Sleep clinical trial. BMC Med Educ. 2025;25(1):267.
85. Métais A, Besnard L, Valero B, Henry A, Schott AM, Rode G, et al. Addressing medical students' health challenges: codesign and pilot testing of the preventive remediation for optimal medical students (PROMESS) program. BMC Med Educ. 2025;25(1):812.

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