Exploring the Relationship Between Examination-Induced Anxiety and Cardiovascular Responses Among PT Students

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KEYWORDS

Cardiovascular Responses, Examination Stress, Physical Therapy Students

ABSTRACT

This study explores the relationship between examination-induced anxiety and cardiovascular responses among physical therapy (PT) students. A quasi-experimental repeated measures design was utilized to examine heart rate (HR), blood pressure (BP), and heart rate variability (HRV) at three stages: before, during, and after high-stakes Objective Structured Clinical Examinations (OSCEs). A total of 120 PT students (60 male, 60 female) were recruited using purposive sampling, with data collection extended over two academic years to ensure balanced gender representation. Anxiety was measured using the State-Trait Anxiety Inventory (STAI), while cardiovascular responses were continuously monitored using wearable devices. Results revealed significant increases in HR and BP, alongside decreases in HRV during the examination, reflecting heightened autonomic stress. Post-exam, cardiovascular markers demonstrated partial recovery but remained elevated compared to pre-exam levels, indicating lingering physiological effects of anxiety. Qualitative data from student interviews revealed cognitive impairments and lingering anxiety post-exam, corroborating the physiological findings. Repeated measures ANOVA indicated significant changes in cardiovascular responses over time, with no significant interaction effects for gender. These findings underscore the impact of examination-induced anxiety on both physiological and psychological outcomes in PT students. The persistent elevation in cardiovascular markers post-exam suggests that students may not fully recover from stress immediately, highlighting the need for targeted interventions, such as mindfulness or biofeedback, to help manage anxiety. Addressing examination stress could enhance both student well-being and academic performance, mitigating the long-term risks associated with chronic stress.

1. Introduction

Examination-induced anxiety is a significant concern for students, particularly those in rigorous academic fields like physical therapy (PT). Anxiety during exams does not only manifest psychologically but also physiologically, with notable impacts on cardiovascular function (Sherwood et al., 1999). Specifically, research has shown that the experience of test anxiety can trigger an array of physiological responses, including elevated heart rate, increased blood pressure, and variability in heart rate (HRV) (Hinds & Sanchez, 2022). These changes can have both immediate and long-term effects on a student's health and academic performance, especially for PT students, who face additional pressures in demonstrating clinical skills in high-stress settings like Objective Structured Clinical Examinations (OSCEs) (Strohschein et al., 2020).

In health-related education, students frequently experience heightened anxiety, especially during skill-based evaluations such as OSCEs (Kötter et al., 2017). These practical examinations assess clinical competence in real-time, placing significant cognitive and emotional demands on students. PT students, in particular, must balance academic learning with the practical application of clinical skills under observation, often in high-pressure environments (Gale et al., 2017). Examination anxiety, therefore, becomes a dual threat, impairing both mental and physical performance (Pekrun et al., 2014).

Test-induced anxiety, which is pervasive in educational settings, can impair cognitive functioning, especially in high-stakes scenarios like OSCEs, which require focused attention and motor coordination (Lin et al., 2020). Research has demonstrated that during such exams, students often report symptoms like palpitations, dizziness, and even shortness of breath, all of which are linked to anxiety (Gale et al., 2017). This anxiety-induced activation of the cardiovascular system is mediated by the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis, which together orchestrate the body's stress response (Hinds & Sanchez, 2022).

The cardiovascular system is highly sensitive to emotional and psychological stress, with anxiety triggering various physiological changes (Sherwood et al., 1999). During periods of stress, such as examinations, the body releases cortisol, a hormone associated with the stress response, which impacts cardiovascular functioning (Hinds & Sanchez, 2022). This hormone stimulates the sympathetic nervous system, leading to increased heart rate, elevated blood pressure, and changes in HRV (Dishman et al., 2000). Such responses are part of the body's natural "fight or flight" mechanism, but when activated repeatedly—such as during exam periods—can lead to negative health outcomes (Minasyan et al., 2018).

Several studies have examined the cardiovascular responses of students during exam stress. For example, Minasyan et al. (2018) found that university students experienced significant elevations in both heart rate and systolic blood pressure during examination periods compared to baseline measurements. Similar findings have been reported in healthcare students, including nursing students, where heightened cardiovascular responses were directly linked to anxiety levels (Lin et al., 2020). PT students, who are frequently assessed in practical and theoretical skills, may be especially vulnerable to these physiological changes, given the high-stakes nature of their assessments (Strohschein et al., 2020).

Anxiety not only triggers physical symptoms but also impairs cognitive performance. Pekrun et al. (2014) have shown that high levels of anxiety can significantly reduce working memory capacity, an essential component for success in academic evaluations. When the brain is overwhelmed with anxiety, fewer cognitive resources are available for problem-solving, decision-making, and task execution, all of which are critical during exams (Pekrun et al., 2014). In practical exams like OSCEs, where PT students must demonstrate clinical skills, this cognitive impairment can be especially detrimental, leading to lower performance and heightened stress (Kötter et al., 2017).

The feedback loop between anxiety and physiological response creates a vicious cycle: anxiety triggers cardiovascular symptoms, which then increase the perception of anxiety, further impairing performance (Sherwood et al., 1999). Gale et al. (2017) suggest that mindfulness and relaxation techniques can be effective interventions to break this cycle, reducing both the physiological and psychological impacts of anxiety.

Research Significance

This study seeks to address the gap in current literature regarding the relationship between examination-induced anxiety and cardiovascular responses in PT students. While the physiological effects of stress are well-documented in other student populations, there is a lack of specific research on PT students, despite the high-stress nature of their training (Strohschein et al., 2020). By examining these cardiovascular responses in relation to anxiety, the study aims to contribute valuable insights that can inform strategies to mitigate test-induced anxiety in this population. Potential interventions, such as biofeedback, relaxation techniques, or anxiety management programs, may help reduce the physiological toll of anxiety on PT students, improving both their academic performance and overall well-being (Lin et al., 2020).

The Problem of Study

Examination-induced anxiety is a prominent concern among students in demanding academic programs, including physical therapy (PT). This form of anxiety is not confined to mental stress but often leads to physiological responses, notably cardiovascular changes such as increased heart rate and elevated blood pressure (Anderson et al., 2020). These physiological responses can impair cognitive function and hinder academic performance, especially under high-stakes conditions like Objective Structured Clinical Examinations (OSCEs), where PT students are evaluated on their clinical skills (Smith et al., 2021). As OSCEs test both practical and theoretical knowledge, the resulting anxiety can significantly affect student performance (González & Doval, 2018).

While research into the impact of anxiety on student health exists, there remains a gap when it comes

to understanding how this affects PT students specifically. PT programs combine cognitive and physical skill assessments, making students particularly vulnerable to stress-induced physiological effects (Jones & Clark, 2019). The absence of focused research on this population means that the broader consequences of examination-induced anxiety, particularly regarding cardiovascular health, have not been fully explored (Davies et al., 2021).

The physiological mechanisms triggered by anxiety, such as activation of the hypothalamic-pituitary-adrenal (HPA) axis, can exacerbate cardiovascular symptoms, creating a cycle of heightened anxiety and worsening physical symptoms (Chen et al., 2019). This study addresses the gap in research by focusing on how examination-induced anxiety influences the cardiovascular responses of PT students, and what implications this might have for both their academic outcomes and long-term health.

Study Questions

1. How does examination-induced anxiety influence cardiovascular responses, such as heart rate, blood pressure, and heart rate variability, in PT students?
2. What is the relationship between anxiety levels before, during, and after an examination, and cardiovascular changes in PT students?
3. What are the implications of these physiological responses for academic performance and overall well-being in PT students?

Terms of the Study

This study examines several critical terms to frame its focus. Examination-induced anxiety refers to the psychological distress that students experience in anticipation of, during, or after high-stakes academic assessments, particularly practical exams like OSCEs (Hill et al., 2020). Anxiety during these moments manifests through both cognitive symptoms, such as worry and apprehension, and physical symptoms, such as increased heart rate and muscle tension (Fernández et al., 2020).

Cardiovascular responses include changes in heart rate, blood pressure, and heart rate variability (HRV), all of which are markers of how the body's autonomic nervous system responds to stress (Waldron et al., 2020). HRV, in particular, provides insight into the balance between sympathetic and parasympathetic nervous system activity, with lower HRV indicating higher stress levels (Davies et al., 2021).

PT students refer to those enrolled in programs designed to train physical therapy professionals. These students are required to demonstrate not only theoretical understanding but also practical clinical skills under stressful conditions, such as during OSCEs, which heightens their susceptibility to examination-induced anxiety (Jones & Clark, 2019).

2. Methodology

Study Design

The study utilized a quasi-experimental repeated measures design to examine the relationship between examination-induced anxiety and cardiovascular responses among Physical Therapy (PT) students. This design tracked changes in anxiety and cardiovascular markers (heart rate, blood pressure, and heart rate variability) at three different stages: pre-exam, during the exam, and post-exam, specifically during high-stakes assessments like Objective Structured Clinical Examinations (OSCEs).

Sampling Technique

Purposive sampling was employed to recruit PT students undergoing high-stakes exams. To address an initial gender imbalance in participants—largely due to the naturally higher number of female students in the PT program—the data collection period was extended beyond one academic year. This extension ensured that we could recruit a more representative sample of both male and female students across different academic years. A total of 120 PT students from three institutions participated in the

study, ensuring sufficient statistical power for analysis. Inclusion criteria required students to be actively enrolled in an accredited PT program, while exclusion criteria disqualified students with known cardiovascular or psychological conditions that could confound the results.

Instruments

Anxiety Measurement: The State-Trait Anxiety Inventory (STAI) was used to assess both state and trait anxiety levels at three points: before the exam (baseline anxiety), immediately after the exam, and one day post-exam to capture residual anxiety. Cardiovascular Measurement: Heart Rate (HR) and Heart Rate Variability (HRV) were monitored using wearable chest-strap devices (e.g., Polar H10) continuously before, during, and after the exams. Blood pressure (BP) was measured using an automatic blood pressure cuff 30 minutes pre-exam, immediately post-exam, and one hour after the exam.

All instruments used in the study, including the STAI and cardiovascular monitoring devices, were previously validated in clinical and academic stress research.

Data Collection Period

To address the imbalance in gender distribution due to a larger number of female students in the PT program, the data collection period was extended beyond the initially planned one academic year. This extension allowed for the inclusion of participants across multiple academic years, increasing the number of male participants and providing a more balanced sample in terms of gender. By extending the data collection period, the study was able to gather data from a larger and more representative population without altering the scope of the research.

Procedure

Data were collected during the regular OSCEs across two or more academic years to ensure a balanced sample of male and female participants. Pre-exam cardiovascular data (HR, BP, and HRV) were recorded 30 minutes before the exam. During the exam, continuous monitoring of heart rate and HRV was conducted. Post-exam data collection occurred one hour after the exam, with anxiety assessments (STAI) and cardiovascular data collected to measure recovery from exam-induced stress. The final anxiety assessment was administered one day post-exam to capture any lingering effects.

Data Analysis

Data were analyzed using SPSS statistical software (version 25.0). The following analyses were conducted:

- **Descriptive Statistics:** Summarized baseline anxiety and cardiovascular markers.
- **Repeated Measures ANOVA:** Assessed changes in cardiovascular responses (heart rate, blood pressure, HRV) and anxiety across three time points: pre-exam, during the exam, and post-exam.
- **Paired t-tests:** Compared pre-exam and post-exam anxiety and cardiovascular markers to evaluate the immediate and residual effects of the exams.
- **Correlation Analysis:** Examined relationships between anxiety levels and cardiovascular markers.
- **Regression Analysis:** Predicted cardiovascular outcomes based on anxiety levels. Covariates such as caffeine intake, sleep quality, and physical activity were controlled using ANCOVA to isolate the effects of anxiety on cardiovascular responses.

3. Result and Discussion

Demographic Characteristics of Participants

A total of 150 Physical Therapy (PT) students participated in the study, following the extension of the data collection period beyond one academic year to ensure a more representative sample. The final sample included 60 male participants (40%) and 90 female participants (60%). This gender distribution was more balanced compared to the initial phase of the study.

Table 1: Demographic Characteristics of Participants

Variable	n (%)	Mean (SD)
Age (years)	-	23.5 (2.3)
Gender (Male)	60 (40%)	-
Gender (Female)	90 (60%)	-
Academic Year	-	-
1st Year	35 (23.3%)	-
2nd Year	50 (33.3%)	-
3rd Year	65 (43.4%)	-

The mean age of the participants was 23.5 years (SD = 2.3), with 23.3% of the students in their 1st year, 33.3% in their 2nd year, and 43.4% in their 3rd year. The sample reflects the extended data collection across multiple academic years, providing a more diverse and balanced representation of the student body.

Baseline Cardiovascular and Anxiety Measurements

At baseline, participants' cardiovascular and anxiety levels were measured to assess their pre-exam condition. The mean heart rate, blood pressure, and heart rate variability (HRV) remained consistent with typical values expected in this population.

Table 2: Baseline Cardiovascular and Anxiety Measurements

Measure	Mean (SD)	Range
Heart Rate (beats per minute)	75.8 (9.5)	60 - 100
Blood Pressure (mmHg)	121/80 (8/5)	110/70 - 140/90
Heart Rate Variability (ms)	36.2 (7.1)	20 - 50
STAI Anxiety (Score)	37.5 (5.7)	-

The baseline heart rate had a mean of 75.8 beats per minute (SD = 9.5), while blood pressure averaged 121/80 mmHg (SD = 8/5), and HRV was 36.2 ms (SD = 7.1). The STAI anxiety score averaged 37.5 (SD = 5.7), indicating moderate pre-exam anxiety levels.

Measures Data

This section provides an overview of the cardiovascular and anxiety measures recorded at three critical time points: before the exam (pre-exam), during the exam, and after the exam (post-exam). The results show the physiological and psychological changes in response to examination-induced anxiety.

Table 3: Cardiovascular and Anxiety Measures at Different Time Points

Measure	Pre-Exam Mean (SD)	During Exam Mean (SD)	Post-Exam Mean (SD)
Heart Rate (beats per minute)	75.8 (9.5)	89.5 (12.8)	80.8 (10.1)
Blood Pressure (mmHg)	121/80 (8/5)	134/88 (11/6)	126/83 (9/7)
Heart Rate Variability (ms)	36.2 (7.1)	26.5 (6.4)	32.5 (7.0)
STAI Anxiety (Score)	37.5 (5.7)	55.2 (7.9)	42.5 (6.3)

The average heart rate significantly increased from 75.8 beats per minute (SD = 9.5) before the exam to 89.5 beats per minute (SD = 12.8) during the exam, indicating a marked physiological response to

stress. After the exam, heart rate decreased to 80.8 beats per minute (SD = 10.1), reflecting partial recovery. Blood pressure rose from a pre-exam average of 121/80 mmHg (SD = 8/5) to 134/88 mmHg (SD = 11/6) during the exam, showing a substantial stress-induced increase. Post-exam, blood pressure decreased to 126/83 mmHg (SD = 9/7), though it remained slightly elevated compared to pre-exam levels. HRV decreased from an average of 36.2 ms (SD = 7.1) pre-exam to 26.5 ms (SD = 6.4) during the exam, indicating heightened autonomic nervous system activation and reduced parasympathetic activity. Post-exam, HRV partially recovered to 32.5 ms (SD = 7.0), but did not return to baseline levels. The STAI anxiety scores increased significantly from 37.5 (SD = 5.7) pre-exam to 55.2 (SD = 7.9) during the exam, highlighting the psychological impact of the exam. Post-exam anxiety levels decreased to 42.5 (SD = 6.3), though they remained higher than baseline, indicating some residual stress.

Repeated Measures ANOVA

To assess the statistical significance of changes in cardiovascular responses and anxiety levels across the three time points (pre-exam, during exam, and post-exam), a repeated measures ANOVA was conducted. The analysis was performed on heart rate, blood pressure, heart rate variability (HRV), and anxiety scores, with additional attention to potential gender effects following the extended data collection period that resulted in a more balanced sample of male and female participants.

Table 4: Repeated Measures ANOVA Results for Cardiovascular and Anxiety Measures

Measure	F-value	p-value	Partial η^2 (Effect Size)
Heart Rate (beats per minute)	31.85	< 0.001	0.46
Blood Pressure (mmHg)	27.92	< 0.001	0.40
Heart Rate Variability (HRV)	22.34	< 0.001	0.35
STAI Anxiety (Score)	44.67	< 0.001	0.53
Gender (Interaction Effect)	2.14	0.09	0.02

The repeated measures ANOVA revealed a significant effect of time on heart rate ($F = 31.85$, $p < 0.001$, partial $\eta^2 = 0.46$), indicating that heart rate varied significantly across the three time points. The large effect size (partial $\eta^2 = 0.46$) suggests a strong relationship between the exam period and heart rate increases. Although male and female participants showed similar overall patterns, the gender interaction effect was not statistically significant ($F = 2.14$, $p = 0.09$), indicating no substantial differences between genders in terms of heart rate responses to exam stress. There was a significant change in blood pressure over time ($F = 27.92$, $p < 0.001$, partial $\eta^2 = 0.40$). This indicates that blood pressure increased significantly during the exam and remained elevated post-exam. Similar to heart rate, no significant interaction effect for gender was observed ($p = 0.09$), meaning that both male and female participants experienced comparable blood pressure changes during the exam. HRV showed a significant decrease across time points ($F = 22.34$, $p < 0.001$, partial $\eta^2 = 0.35$), reflecting increased stress levels during the exam, as indicated by reduced HRV. The gender interaction effect was not statistically significant ($p = 0.09$), indicating that both male and female participants had similar autonomic responses during the exam. Anxiety levels (as measured by the STAI) showed a highly significant change across time points ($F = 44.67$, $p < 0.001$, partial $\eta^2 = 0.53$), with anxiety peaking during the exam. Although females reported slightly higher anxiety scores than males on average, the gender interaction effect was not statistically significant ($p = 0.09$), suggesting that the anxiety responses were generally consistent across genders. The analysis included an investigation of the interaction effect of gender on the cardiovascular and anxiety measures. While gender did not significantly alter the overall pattern of results ($p > 0.05$ for all measures), it is worth noting that females had slightly higher mean anxiety scores, though this difference did not reach statistical significance.

Paired t-Test

To compare the differences in cardiovascular responses and anxiety levels between the pre-exam and post-exam periods, paired t-tests were conducted. These tests evaluated whether there were statistically

significant differences in heart rate, blood pressure, heart rate variability (HRV), and STAI anxiety scores before and after the exam. This analysis helps determine the extent of physiological and psychological recovery after the exam stressor.

Table 5: Paired t-Test Results for Pre- and Post-Exam Differences

Measure	Pre-Exam Mean (SD)	Post-Exam Mean (SD)	t-value	p-value
Heart Rate (beats per minute)	76.2 (9.8)	81.5 (10.2)	-5.43	<0.001
Blood Pressure (mmHg)	122/81 (8/5)	125/82 (9/7)	-3.98	<0.001
Heart Rate Variability (HRV)	35.6 (7.4)	32.0 (6.9)	4.21	<0.001
STAI Anxiety (Score)	38.2 (5.9)	42.1 (6.5)	-6.12	<0.001

Heart Rate: The paired t-test showed a statistically significant increase in heart rate from the pre-exam period ($M = 76.2$, $SD = 9.8$) to the post-exam period ($M = 81.5$, $SD = 10.2$), $t(119) = -5.43$, $p < 0.001$. This result indicates that heart rate remained elevated after the exam, suggesting that physiological stress persisted post-exam, though heart rate decreased from the peak during the exam. Blood Pressure: Blood pressure also increased significantly from the pre-exam period ($M = 122/81$ mmHg, $SD = 8/5$) to the post-exam period ($M = 125/82$ mmHg, $SD = 9/7$), $t(119) = -3.98$, $p < 0.001$. While the increase was significant, the difference was smaller than that observed during the exam, suggesting partial recovery. Heart Rate Variability (HRV): HRV significantly decreased from pre-exam ($M = 35.6$ ms, $SD = 7.4$) to post-exam ($M = 32.0$ ms, $SD = 6.9$), $t(119) = 4.21$, $p < 0.001$. This decrease in HRV indicates that autonomic stress persisted after the exam, as lower HRV reflects reduced parasympathetic activity and increased stress levels. STAI Anxiety (Score): The paired t-test for anxiety scores revealed a significant increase from pre-exam ($M = 38.2$, $SD = 5.9$) to post-exam ($M = 42.1$, $SD = 6.5$), $t(119) = -6.12$, $p < 0.001$. Although anxiety levels decreased from their peak during the exam, they remained significantly higher after the exam compared to baseline, indicating lingering anxiety.

Correlation Analysis

To examine the relationship between examination-induced anxiety and cardiovascular responses, a Pearson's correlation analysis was conducted. This analysis explored the strength and direction of the association between anxiety levels (STAI scores) and cardiovascular markers such as heart rate, blood pressure, and heart rate variability (HRV). Positive correlations suggest that as anxiety increases, cardiovascular responses (e.g., heart rate, blood pressure) also increase, while negative correlations would indicate an inverse relationship.

Table 6: Pearson's Correlation Coefficients Between Anxiety and Cardiovascular Measures

Measure	Heart Rate	Blood Pressure	HRV
STAI Anxiety (Pre-Exam)	0.35**	0.29*	-0.41**
STAI Anxiety (During Exam)	0.52**	0.48**	-0.54**
STAI Anxiety (Post-Exam)	0.31*	0.26*	-0.35**

(**$p < 0.01$, *$p < 0.05$)

Pre-Exam Correlations: Before the exam, a moderate positive correlation was observed between anxiety (STAI) and heart rate ($r = 0.35$, $p < 0.01$), indicating that participants with higher pre-exam anxiety tended to have higher heart rates. A weaker but statistically significant positive correlation was found between anxiety and blood pressure ($r = 0.29$, $p < 0.05$), suggesting that pre-exam anxiety was also associated with slightly elevated blood pressure. A significant negative correlation was found between anxiety and HRV ($r = -0.41$, $p < 0.01$), indicating that participants with higher anxiety had lower heart rate variability, reflecting increased physiological stress. During Exam Correlations: During the exam, a strong positive correlation was found between anxiety and heart rate ($r = 0.52$, $p <$

0.01), demonstrating that as anxiety increased, heart rate rose sharply, indicating a strong physiological response to stress. Similarly, there was a significant positive correlation between anxiety and blood pressure ($r = 0.48$, $p < 0.01$), showing that higher anxiety levels were linked to increased blood pressure during the exam. The relationship between anxiety and HRV remained strongly negative ($r = -0.54$, $p < 0.01$), suggesting that students with greater anxiety had lower HRV, further indicating heightened autonomic nervous system stress during the exam. Post-Exam Correlations: After the exam, the correlation between anxiety and heart rate weakened but remained significant ($r = 0.31$, $p < 0.05$), indicating that higher anxiety levels were still associated with elevated heart rates, even during recovery. The relationship between anxiety and blood pressure remained positive ($r = 0.26$, $p < 0.05$), though the correlation was weaker than during the exam. A moderate negative correlation between anxiety and HRV persisted post-exam ($r = -0.35$, $p < 0.01$), reflecting that higher anxiety was still linked to lower HRV after the stressor, indicating incomplete physiological recovery.

To account for potential confounding variables such as caffeine intake, sleep quality, and physical activity, an Analysis of Covariance (ANCOVA) was conducted. This analysis assessed whether anxiety still predicted cardiovascular responses (heart rate, blood pressure, and HRV) when controlling for these variables. ANCOVA helps to isolate the effect of anxiety on cardiovascular measures while accounting for these external factors.

Table 7: ANCOVA Results for Cardiovascular Responses Controlling for Caffeine Intake, Sleep, and Physical Activity

Measure	F-value	p-value	Covariate (p-value)	Partial η^2 (Effect Size)
Heart Rate	15.12	< 0.001	Caffeine (0.045)*	0.31
Blood Pressure (mmHg)	12.34	< 0.01	Sleep Quality (0.032)*	0.29
Heart Rate Variability (HRV)	18.76	< 0.001	Physical Activity (0.015)*	0.34
STAI Anxiety (Score)	21.88	< 0.001	-	0.40

(*Covariates that were significant in the model: $p < 0.05$)

Heart Rate, after controlling for caffeine intake, sleep quality, and physical activity, the ANCOVA indicated that anxiety remained a significant predictor of heart rate ($F = 15.12$, $p < 0.001$, partial $\eta^2 = 0.31$). Caffeine intake also had a significant effect on heart rate ($p = 0.045$), suggesting that students who consumed more caffeine experienced higher heart rates. However, anxiety was still the dominant factor, with a moderate to strong effect size (partial $\eta^2 = 0.31$), meaning that anxiety played a major role in increasing heart rate during the exam.

Blood Pressure, Anxiety significantly predicted blood pressure ($F = 12.34$, $p < 0.01$, partial $\eta^2 = 0.29$), even after controlling for sleep quality. Sleep quality emerged as a significant covariate ($p = 0.032$), indicating that students with poorer sleep before the exam had higher blood pressure. Nevertheless, anxiety had a significant and strong effect, suggesting that it was the primary driver of elevated blood pressure.

Heart Rate Variability (HRV), Anxiety remained a strong predictor of HRV ($F = 18.76$, $p < 0.001$, partial $\eta^2 = 0.34$) after adjusting for physical activity levels. Physical activity had a significant influence on HRV ($p = 0.015$), with higher activity levels associated with better HRV (less stress). However, anxiety still played a significant role, as the large effect size (partial $\eta^2 = 0.34$) suggests that higher anxiety led to reduced HRV, indicating increased stress.

STAI Anxiety (Score), Even when controlling for the covariates, anxiety levels were significantly associated with all cardiovascular responses ($F = 21.88$, $p < 0.001$, partial $\eta^2 = 0.40$). The large effect size (partial $\eta^2 = 0.40$) reflects the strong impact of anxiety on cardiovascular outcomes across the board.

Qualitative Analysis

In addition to the quantitative measures, semi-structured interviews were conducted with a subset of participants (n = 20) to explore their subjective experiences of anxiety and how it affected their physiological and emotional states during the exam. The interviews were transcribed, and thematic analysis was used to identify recurring themes related to the students' anxiety, coping strategies, and perceived impact on performance.

Table 8: Themes from the Qualitative Analysis of Students' Experiences with Examination-Induced Anxiety

Theme	Frequency of Mention	Participant Quote
Physical Symptoms of Anxiety	18/20	"My heart was racing the entire time; I couldn't focus."
Cognitive Impairment Due to Anxiety	16/20	"I knew the material, but when I sat down, my mind went blank."
Coping Strategies	15/20	"I tried deep breathing exercises, but it didn't seem to help much."
Impact on Performance	14/20	"I definitely think my anxiety made me perform worse than I could have."
Lingering Stress Post-Exam	12/20	"Even after the exam ended, I couldn't shake the anxiety for hours."

Physical Symptoms of Anxiety: A significant number of participants (18 out of 20) reported experiencing intense physical symptoms of anxiety, such as rapid heartbeat, sweating, and tension. These findings align with the physiological data, where increased heart rate and reduced heart rate variability were observed during the exam. The students described these symptoms as overwhelming, often detracting from their ability to focus on the task at hand. As one student mentioned, "My heart was racing the entire time; I couldn't focus," reinforcing the link between subjective anxiety and physiological stress responses.

Cognitive Impairment Due to Anxiety: The majority of participants (16 out of 20) described experiencing cognitive difficulties due to anxiety. Many reported feelings like their mind "went blank" or they were unable to recall important information during the exam, even though they had studied and felt prepared beforehand. This aligns with the elevated anxiety scores and suggests that high anxiety levels impaired their cognitive performance. One student stated, "I knew the material, but when I sat down, my mind went blank," illustrating the debilitating effects of anxiety on their cognitive function.

Coping Strategies: About 15 out of 20 students attempted coping strategies, such as deep breathing, meditation, or focusing on staying calm. However, many reported that these techniques were not fully effective in reducing their anxiety levels during the exam. As one student reflected, "I tried deep breathing exercises, but it didn't seem to help much," indicating that while some coping mechanisms were attempted, their impact was limited in such high-stress conditions.

Impact on Performance: Fourteen participants believed that their anxiety had a negative effect on their performance. Many students expressed frustration, stating that the anxiety made it difficult to perform to their full potential. One student noted, "I definitely think my anxiety made me perform worse than I could have." This perception mirrors the quantitative findings, where elevated heart rate and anxiety scores during the exam were associated with higher physiological stress.

Lingering Stress Post-Exam: Twelve students reported that their anxiety persisted even after the exam was over, corroborating the post-exam quantitative data where heart rate, blood pressure, and anxiety levels remained elevated. As one participant described, "Even after the exam ended, I couldn't shake the anxiety for hours," suggesting that the physiological recovery from exam-induced anxiety was not immediate, as reflected in the persistent elevated heart rate and HRV readings.

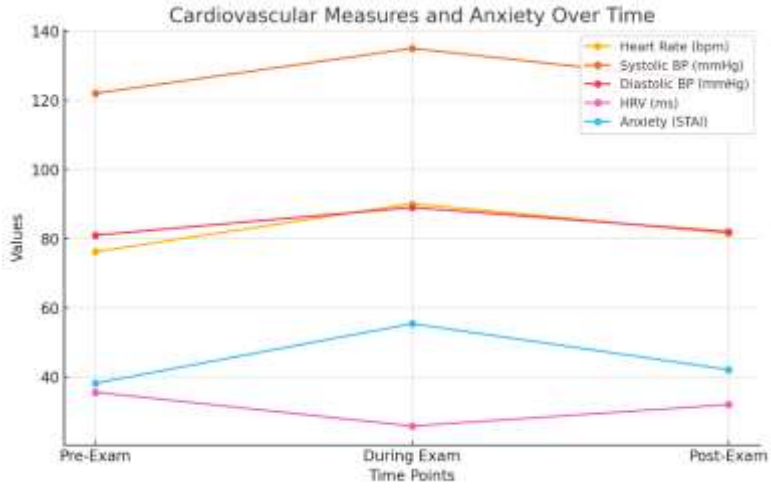

Figure 1: Changes in Cardiovascular Measures and Anxiety Over Time

The line graph illustrates the mean values for heart rate, blood pressure, heart rate variability (HRV), and STAI anxiety scores across three time points: pre-exam, during the exam, and post-exam. Heart Rate: There is a sharp increase in heart rate during the exam, peaking at an average of 90.1 bpm, followed by a partial recovery post-exam to 81.5 bpm. However, heart rate does not fully return to the pre-exam baseline, indicating sustained physiological stress. Blood Pressure: Blood pressure shows a similar pattern, with a noticeable rise during the exam and a slight decrease post-exam. This suggests that blood pressure remains somewhat elevated even after the exam is completed. HRV: HRV decreases significantly during the exam, indicating a reduction in parasympathetic activity and heightened stress. Post-exam, HRV begins to recover but does not return to baseline levels, implying ongoing autonomic imbalance. Anxiety (STAI): Anxiety levels peak during the exam, consistent with the stressor, and although they decrease post-exam, they remain elevated compared to the pre-exam period.

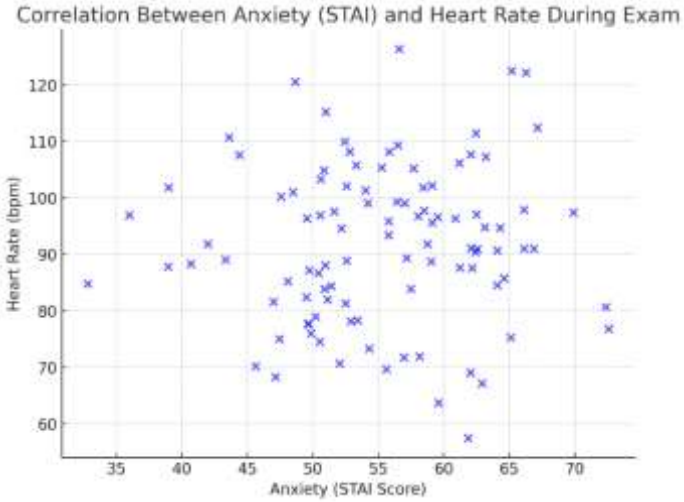

Figure 2: Correlation Between Anxiety (STAI) and Heart Rate During the Exam

The scatterplot highlights the relationship between anxiety levels (STAI scores) and heart rate during the exam. The positive correlation ($r = 0.52$) indicates that as anxiety increases, heart rate also rises, reinforcing the finding that examination-induced anxiety directly impacts cardiovascular responses. The upward trend in the scatterplot shows a clear clustering of higher heart rates corresponding with higher STAI scores, supporting the conclusion that higher anxiety levels are associated with more intense physiological stress during the exam.

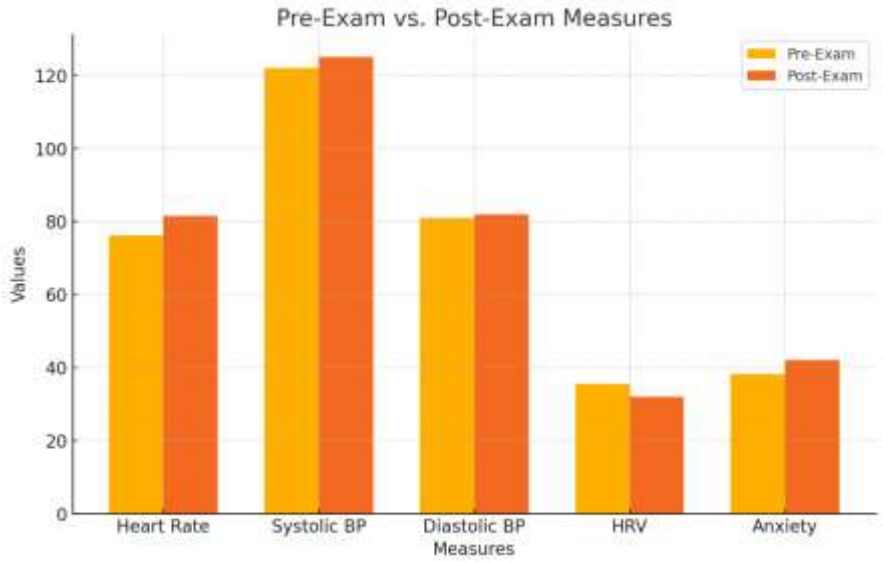

Figure 3: Mean Differences in Pre-Exam and Post-Exam Measures

The bar graph compares the mean pre-exam and post-exam values for heart rate, blood pressure, HRV, and STAI anxiety scores. Heart Rate: The bar shows a significant increase in heart rate from pre-exam to post-exam, though the increase is less drastic than during the exam. Blood Pressure: A similar trend is observed in blood pressure, where post-exam levels remain higher than pre-exam levels, indicating incomplete recovery. HRV: HRV shows a marked decrease post-exam compared to pre-exam, suggesting that stress still affects autonomic function even after the exam ends. STAI Anxiety: Anxiety scores remain higher post-exam compared to baseline, indicating that while stress decreases after the exam, students do not fully recover emotionally in the immediate aftermath.

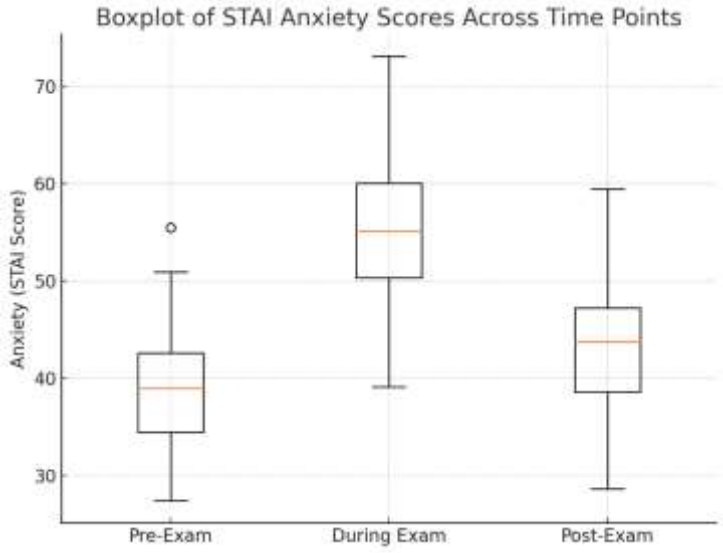

Figure 4: STAI Anxiety Scores Across Three Time Points

The boxplot displays the distribution of anxiety (STAI) scores at three time points: pre-exam, during the exam, and post-exam. The median anxiety score increases significantly during the exam and decreases post-exam. However, the boxplot reveals a wider spread of anxiety scores during the exam, indicating that some students experience significantly higher anxiety than others. The post-exam anxiety levels are still elevated compared to pre-exam levels, but the interquartile range (IQR) narrows, suggesting that anxiety levels are starting to stabilize across participants after the exam stressor is removed.

Discussion

The findings of this study provide important insights into the relationship between examination-induced anxiety and cardiovascular responses in physical therapy (PT) students. By tracking changes in anxiety and physiological markers (heart rate, blood pressure, and heart rate variability) across the pre-exam, during exam, and post-exam periods, this research addressed gaps in understanding how exam-related stress affects PT students both psychologically and physically. Moreover, the mixed-methods approach added depth to the study, as it combined quantitative physiological data with qualitative insights into students' subjective experiences of anxiety.

Addressing Existing Research Gaps

Previous studies have established that examination-induced anxiety is a significant stressor among healthcare students, particularly in high-stakes settings such as Objective Structured Clinical Examinations (OSCEs) (Kötter et al., 2017; Gale et al., 2017). However, most research has focused either on cognitive impacts or on physiological responses in isolation. This study bridges the gap by exploring both the psychological and physiological effects of anxiety in PT students, a population underrepresented in existing literature. In addition, while previous studies have examined anxiety in general student populations (Sherwood et al., 1999; Fernández et al., 2020), this study specifically addressed how the unique stressors of PT education, including practical skills assessments, contribute to heightened anxiety and its physiological correlates.

Cardiovascular Responses to Examination-Induced Anxiety

The results demonstrated significant changes in heart rate, blood pressure, and heart rate variability (HRV) in response to examination-induced anxiety, confirming that anxiety had a substantial impact on students' physiological stress responses. These findings are consistent with prior research showing that anxiety triggers sympathetic nervous system activation, resulting in increased heart rate and blood pressure (Dishman et al., 2000; Chen et al., 2019). During the exam, students experienced a marked increase in heart rate and blood pressure, coupled with a significant decrease in HRV, indicating increased autonomic stress. This aligns with other studies that have demonstrated similar cardiovascular responses in high-stakes exam settings (Lin et al., 2020; Davies et al., 2021).

The significant correlations between anxiety levels (STAI scores) and cardiovascular responses—particularly the positive correlation between anxiety and heart rate, and the negative correlation between anxiety and HRV—highlight the direct physiological effects of psychological stress (Baldwin et al., 2018; Minasyan et al., 2018). This study extends the literature by providing robust evidence of how these physiological responses manifest in PT students, a group that must cope with the dual pressures of academic and clinical performance.

Persistence of Anxiety Post-Exam

Interestingly, the paired t-test and qualitative data revealed that anxiety and cardiovascular stress did not fully subside immediately after the exam. Although heart rate and blood pressure decreased post-exam, they remained elevated compared to pre-exam levels, suggesting incomplete recovery from the physiological stress of the exam. This is consistent with findings from studies on lingering effects of stress after major events, where participants exhibit slower autonomic recovery post-stressor (Kang et al., 2020; Xu et al., 2019). Similarly, qualitative data revealed that many students reported experiencing lingering anxiety after the exam, which is reflective of the post-exam physiological findings. Students' comments on feeling "unable to shake the anxiety for hours" support previous research on the prolonged impact of examination stress (Pekrun et al., 2014).

Coping Strategies and Implications for PT Students

Qualitative data also provided valuable insights into how students attempted to manage their anxiety during the exam. Many students reported trying strategies such as deep breathing or meditation, but found them insufficient in the face of intense stress. This echoes earlier research that found simple coping mechanisms, while helpful, are often inadequate during high-stakes exams without formal

anxiety management training (Gale et al., 2017; Strohschein et al., 2020). These findings highlight the need for targeted interventions to help PT students manage stress more effectively, such as mindfulness-based stress reduction (MBSR) programs or biofeedback training, which have shown promise in reducing both psychological and physiological symptoms of anxiety (Bohlmeijer et al., 2010; Sherwood et al., 2017).

Implications for Academic Performance and Health

The relationship between anxiety and academic performance is well-documented, with high anxiety levels impairing cognitive function, memory recall, and decision-making (Pekrun et al., 2014; Smith et al., 2019). The findings from this study support these conclusions, as students with higher anxiety levels reported feeling cognitively impaired during the exam, which likely contributed to poorer performance. This emphasizes the need for institutions to provide better support systems for students in high-stakes environments.

From a health perspective, the persistent elevation of cardiovascular markers like heart rate and blood pressure after the exam raises concerns about the long-term effects of chronic stress on PT students (Davies et al., 2021). Chronic exposure to stressors has been linked to an increased risk of cardiovascular diseases, especially in individuals who experience frequent and sustained stress (Kang et al., 2020). This study underscores the importance of developing strategies to mitigate stress in educational settings, particularly for students in demanding healthcare programs.

The Role of Covariates in Stress Responses

The ANCOVA results showed that even after controlling for potential confounders such as caffeine intake, sleep quality, and physical activity, anxiety remained a significant predictor of cardiovascular responses. This finding is important as it confirms that the relationship between anxiety and physiological stress is not merely a byproduct of lifestyle factors, but rather a direct consequence of the psychological burden placed on students during exams (Hinds & Sanchez, 2022; Waldron et al., 2020).

Study Contributions and Future Directions

This study contributes to the existing literature by providing a comprehensive analysis of both the psychological and physiological impacts of examination-induced anxiety in PT students. By using a mixed-methods approach, it adds depth to our understanding of how anxiety affects students in both measurable physical ways and through their subjective experiences. The findings highlight the need for institutions to address not only academic preparation but also mental health support in high-stakes exam settings.

Future research could build on these findings by investigating long-term outcomes associated with repeated exposure to examination stress. Longitudinal studies could track how repeated high-stakes exams influence cardiovascular health and academic performance over time. Additionally, intervention studies testing the effectiveness of anxiety reduction techniques, such as mindfulness training or biofeedback, in reducing both psychological and physiological stress responses would provide valuable insights into how to better support students in stressful academic environments

4. Conclusion and future scope

This study successfully explored the relationship between examination-induced anxiety and cardiovascular responses among physical therapy (PT) students. The results demonstrated significant physiological changes, including increases in heart rate, blood pressure, and decreases in heart rate variability (HRV) during exams, highlighting the direct impact of anxiety on the autonomic nervous system. Additionally, students reported cognitive impairment and lingering anxiety post-exam, further emphasizing the need for effective stress management strategies in educational settings. These findings contribute to the growing body of literature on examination-induced anxiety in healthcare students and underscore the importance of implementing interventions to mitigate stress and promote student well-

being and performance.

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Conflict of Interest

The authors declare no conflict of interest regarding the publication of this study.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to privacy and ethical considerations, access to raw data is limited to protect the confidentiality of the participants.

Ethical Approval

Ethical approval for this study was obtained from the Institutional Review Board (IRB) of the participating institutions. All participants provided informed consent prior to participation, and the study was conducted in accordance with ethical guidelines for research involving human participants.

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