education sciences

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Understanding the Psycho-Physiological Impact of Bullying on Adolescents: A Focus on Movement-Based Educational Interventions

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Abstract: Bullying and cyberbullying are significant challenges faced by children and adolescents in their daily lives, often leading to severe psychological and physiological harm. A promising avenue of research in this area focuses on the physiological stress responses triggered by bullying experiences. This study aimed to examine the potential of group task-oriented physical education as a mediator between bullying and stress-related physiological responses, particularly in relation to heart rate variability. A secondary objective was to design and assess a program for stress management, named BOND (Building Opportunities through Networked Dynamics), tailored for physical education settings. The study employed a two-arm randomized parallel-group design, involving 160 students (average age = 14.67 years, SD = ±0.61) from two schools in southern Italy. The participants were split into two groups: one group attended the BOND program (held twice a week for 60 min), while the other took part in regular physical education classes, (conducted twice a week for 60 min). Measurements were taken both before and after the intervention. Students underwent assessments that included the Coping Questionnaire for Children and Adolescents, the Perceived Stress Scale, and measurements of vagus-mediated heart rate variability. The findings underscore the positive impact of the BOND program on the psycho-physiological well-being of students affected by bullying, highlighting the significant potential of a simple yet effective intervention in safeguarding student well-being and mitigating the adverse effects of bullying. However, future research is necessary to provide a more comprehensive understanding of this phenomenon.

Keywords: sport; physiology; cardiac activity; stress; academic achievement

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Academic Editor: Eleni Andreou

Received: 31 January 2025
Revised: 16 April 2025
Accepted: 22 April 2025
Published: 23 April 2025

Citation: Latino, F., Tafuri, D., & Tafuri, F. (2025). Understanding the Psycho-Physiological Impact of Bullying on Adolescents: A Focus on Movement-Based Educational Interventions. *Education Sciences*, *15*(5), 521. https://doi.org/10.3390/educsci15050521

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1. Introduction

The phenomenon of school bullying, given the significant immediate and long-term effects on children's physical and psychological well-being (Ttofi & Farrington, 2008), has increasingly attracted attention from both the public and academic communities. Numerous studies highlight that the school setting is the preferred environment for bullies due to the simultaneous presence of many young people, the extended time spent together, and the existence of spaces with limited adult supervision (such as hallways, bathrooms, and locker rooms). For this reason, it is crucial to examine bullying within this context.

Bullying is distinguished from other forms of violence by its specific characteristics: intentionality, systematicity, and the power imbalance between the individuals involved

(Smokowski & Kopasz, 2005). It can manifest in various forms, including physical bullying (shoving, hitting, assaults), verbal bullying (insults, threats, mockery), and online bullying (spreading false or embarrassing information on social media) (Bakar, 2021). According to the U.S. CDC, bullying is defined as "any unwanted aggressive behavior by one or more youths, who are not siblings or friends, that involves a perceived or observed imbalance of power and is repeated or likely to be repeated, causing physical, psychological, social, or educational harm or distress" (Man et al., 2022). Both bullying and cyberbullying have devastating psychological and physiological consequences for victims. Among the most promising areas of research is the study of physiological responses to stress caused by these phenomena (Gohal et al., 2023). Stress is defined as the body's response to harmful stimuli that disrupts internal balance, leading to psychophysical and behavioral changes aimed at defending the organism. This process involves events or situations that challenge an individual's ability to adapt, activating physiological, emotional, and cognitive reactions (Rauschenberg et al., 2021).

Among physiological responses to stress, heart rate variability (HRV) has gained attention as a potential indicator of mental health (Tiwari et al., 2021). HRV, regulated by both the sympathetic and parasympathetic systems, reflects the heart's adaptability to external stimuli. However, exposure to intense or prolonged stress can alter the stress response system, reducing parasympathetic activity and, consequently, HRV (Schubert et al., 2009). Studies on victims of bullying have shown increased physiological stress responses and a correlation between low HRV and experiences of victimization (Behnsen et al., 2020). According to the polyvagal theory (Porges, 2007), reduced autonomic regulation impedes adaptive reactions to environmental stimuli, undermining the ability to manage stressful social interactions. HRV, measured through linear and non-linear methods, is a non-invasive tool for assessing the autonomic nervous system's activity. It is influenced by factors such as physical activity, breathing, and emotional states (Tripska et al., 2022).

Recent research has demonstrated the feasibility of using HRV in educational and school-based contexts through the implementation of wearable devices capable of continuous or session-based monitoring. These devices, including wrist-worn sensors and chest straps, allow for the collection of physiological data in ecologically valid environments without disrupting students' daily routines. For instance, Schlink et al. (2022) successfully employed wearable HRV monitors to investigate the physiological effects of social stressors among adolescents in school settings, highlighting the sensitivity of HRV as a marker of relational stress. Similarly, Bass et al. (2019) used wearable biosensors to monitor students' autonomic responses during emotionally demanding classroom situations, establishing the validity of HRV for capturing in-the-moment stress. Moreover, Reiss et al. (2019) integrated HRV measures into a broader school-based mental health intervention, demonstrating how physiological data can inform and support tailored educational strategies for stress regulation.

This approach is particularly useful in studying the impact of bullying, as it enables researchers to detect autonomic responses in real time during or following stressful social experiences (e.g., peer interactions, exclusion, or confrontation). By integrating HRV measurement with contextual data (e.g., observational protocols or self-reports), it becomes possible to identify specific patterns of physiological dysregulation associated with victimization and social stress within school settings (Latino et al., 2021).

In this context, physical activity emerges as a powerful mechanism to reduce stress and increase HRV (Vogel et al., 2022). Educational programs in schools have utilized physical education to mitigate bullying, fostering social skills and cooperative behaviors (Zych et al., 2019a). These interventions, targeting both bullies and victims, aim to reduce relational aggression and promote more adaptive responses (Ramírez & Lacasa, 2013).

Physical education, designed as a cooperative activity, has been shown to improve group dynamics, reduce anxiety and depression, and encourage positive relationships among students (Philippot et al., 2021). However, many studies have only partially evaluated the underlying mechanisms, often with samples limited to adult populations or lacking control groups, leaving room for further investigation (Thériault-Couture et al., 2024). To effectively address bullying, greater focus on victims and social costs is needed, with intervention programs that utilize physical education as a central strategy and that integrate physiological indicators like HRV to assess and guide their impact.

In an effort to use physical education as a tool to combat bullying, intervention programs have been developed to promote both personal and social growth (Fuller et al., 2013). These initiatives play a pivotal role in fostering positive relationships among students (Méndez et al., 2019). A systematic review by Jiménez-Barbero et al. (2016) explored the relationship between school bullying and physical education, highlighting the potential of this discipline to nurture attitudes and behaviors that deter violence and bullying. This review identified significant opportunities for innovation and research to strengthen the scientific foundation of related intervention strategies.

Prominent international organizations, particularly those influential in sports, like Futbol Club Barcelona, have launched specialized programs to address bullying in schools through physical education. These initiatives have been linked to a decrease in reported cases of bullying (Roca-Campos et al., 2022). For instance, Calmaestra et al. (2020) implemented an intervention in primary education that combined physical education with art and various exercises to tackle bullying. Other studies have also examined the use of physical education in addressing aggression. Jiménez-Barbero et al. (2016) reported on two interventions in secondary schools that incorporated martial arts and self-defense techniques in physical education to reduce violent behaviors. However, these interventions primarily focused on fostering positive attitudes and reducing aggression rather than directly targeting bullying. Conversely, Oliveira et al. (2017) conducted a three-month intervention using cooperative games in physical education to address bullying, focusing on verbal and physical aggression. This study lacked a control group and underscored the need for carefully structured environments to effectively develop cooperative skills (Cronin et al., 2020; Valentini & Gennari, 2024). Philippot et al. (2021) noted that physical activities presented as games can reduce anxiety and depression in non-clinical populations. These activities, designed to be enjoyable and non-competitive, encouraged positive social interactions among participants. The researchers concluded that systematically organized group physical activities can improve mood and peer relationships, benefiting all participants, especially those who are shy, insecure, or less athletically inclined. Additionally, experiences of relational victimization in schools have been linked to lower heart rate variability (HRV) in children aged 6 to 10 years (Massing-Schaffer et al., 2019). Similarly, children exhibiting stress-related symptoms have shown reduced HRV and elevated heart rates compared to control groups (Tomasi et al., 2024). These findings underline the physiological impact of stress and highlight the potential of interventions, such as physical education, to address the psychological and social challenges associated with bullying.

The present study aims to investigate the effects of an intervention based on physical education on bullying victimization, stress symptoms, and heart rate variability (HRV). Specifically, the study focuses on the BOND program, a group-task-oriented physical education intervention, and its potential to reduce perceived stress levels and improve students' social skills. This approach arises from the need to overcome traditional physical education programs that, while beneficial in promoting physical health, often lack a focused approach on developing social skills, emotional regulation, and specific bullying prevention strategies. Previous experiential courses have shown limitations in addressing these areas

due to their generalized nature and the absence of structured group tasks that enhance cooperation, empathy, and resilience. The BOND program, a specialized physical education curriculum, was designed to address these shortcomings. It integrates group-task-oriented activities aimed at fostering social cohesion, emotional regulation, and effective stress management, making it particularly suitable for addressing the complex dynamics of bullying. This structured approach allows for the simultaneous development of physical, emotional, and social skills, offering a holistic intervention that goes beyond the goals of traditional physical education programs.

Therefore, the primary objective is to assess whether participation in the BOND program leads to a decrease in bullying experiences and a positive change in psychosocial indicators, such as stress regulation and social competence. The study hypothesizes that students participating in the BOND program will show improved stress management and enhanced social development, compared to those engaged in regular physical education programs. By exploring the effectiveness of targeted school-based interventions, this study contributes to the growing body of research on promoting resilience and well-being in adolescents.

2. Materials and Methods

2.1. Study Design

This empirical study adopted a two-arm randomized parallel-group design to investigate the potential mediating role of a group task-oriented physical education program in the connection between bullying and physiological stress in secondary school students.

The research took place over 12 weeks, with participants randomly assigned to either the experimental group or the control group. Randomization was carried out using a simple randomization approach, with a random number table and an electronic tool to generate numerical sequences. The allocation rule assigned participants with even-numbered digits to the experimental group (EG) and those with odd-numbered digits to the control group (CG). Following this randomization, an initial equivalence check was conducted between the two groups, utilizing a double-blind method to ensure that neither participants nor researchers were aware of the group assignments. While participants were informed about the study's objectives and the general procedures, they were blinded to their specific group assignment. Researchers who conducted the assessments were also unaware of the group assignments to prevent any potential bias during data collection.

Throughout the study period, the experimental group participated in a group-task-oriented physical education program, called "BOND—Building Opportunities through Networked Dynamics" (two 60 min sessions per week), while the control group continued with standard physical education classes (also two 60 min sessions per week).

The study ran from September 2024 to December 2024 and adhered to the ethical guidelines established in the Helsinki Declaration and its subsequent revisions. The protocol was reviewed and approved by the Department of Medical Science, Exercise, and Wellbeing at the University of Naples "Parthenope" (DiSMMeB Prot. N. 88592/2024).

2.2. Participants

A total of 160 individuals, aged between 14 and 15 years (average age = 14.67, SD = $\pm$0.61), were selected from two local schools in southern Italy, known for frequent bullying incidents (especially among first-year students). The study was open to all first-year students at the selected schools, with participation being entirely voluntary. Inclusion criteria included students who were currently enrolled in one of the two schools, capable of completing a moderate-to-vigorous intensity aerobic exercise session, and able to refrain from any physical activity outside of the study protocol on test days. Students with ortho-

pedic or cardiovascular conditions that prevented them from engaging in physical exercise were excluded, as were those who were unable to refrain from any physical activity outside the study protocol on designated testing days.

A total of 160 participants (67 females and 93 males) met the inclusion criteria and were invited to participate in the study. All recruited participants agreed to participate in the study (Figure 1). Two weeks before the program began, participants received an email outlining comprehensive details about the study. Parents of all participants gave their informed consent prior to involvement. The study emphasized that participation was completely voluntary, and researchers took measures to guarantee the privacy and confidentiality of participants' data. A comprehensive description of the study's objectives was given to all participants, outlining the specific research procedures, and written consent was obtained from all participants. To minimize the risk of information exchange between participants from different groups, participants were instructed not to discuss their group assignments with each other.

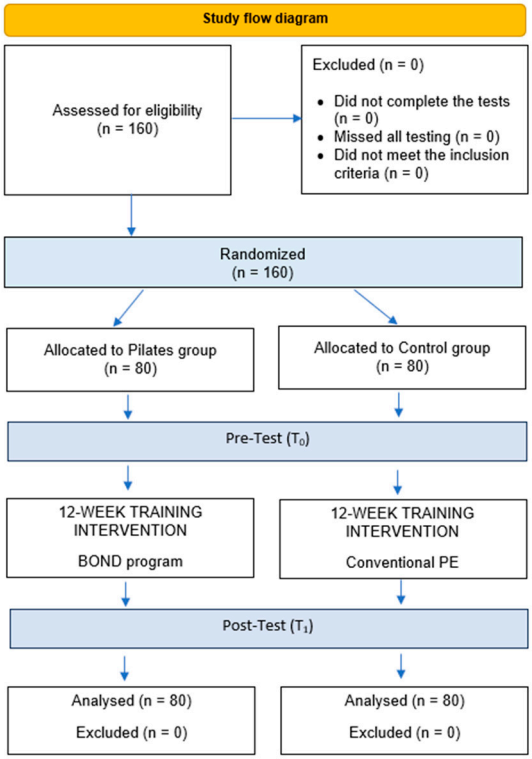


Figure 1. Study flow diagram.

2.3. Procedures

The program was implemented in a school gymnasium, where it was conducted under strict supervision and controlled conditions. The sessions were incorporated into the regular physical education timetable, taking place twice a week, each lasting 60 min.

Prior to the first session, an initial assessment was performed to clarify the details of the exercise program and gauge each participant's motivation. Two days before the intervention began, participants completed two assessments. The first focused on their psychological well-being, utilizing the Perceived Stress Scale (PSS) to measure their perceived stress levels. The second assessment involved a physiological evaluation (HRV) to analyze the stress responses of the students. Both the psychological and physiological assessments were repeated before and after the intervention, allowing for a comparison of the data to assess the effects of the program. The assessments were conducted at the same time of day to ensure consistency in the experimental conditions.

Throughout the intervention, participants wore suitable athletic attire and sports footwear. The program was overseen by a certified physical education instructor, while an experienced researcher handled the testing. All sessions adhered to a standardized protocol to maintain uniformity. The assessments and physical activity sessions were planned and supervised by two qualified physical education teachers.

During the intervention period, participant adherence and engagement were systematically monitored to ensure the fidelity of the implementation. Attendance was recorded at each session by the researchers, and participation levels were assessed using observational checklists designed to capture indicators such as active involvement in proposed activities, responsiveness to instructions, and interaction with peers. These tools provided both quantitative and qualitative data on individual engagement. The adherence rate was high: 89% of participants attended at least 85% of the sessions. Instances of absence were minimal and primarily due to documented personal or health-related reasons. This monitoring process contributed to maintaining the integrity and consistency of the intervention across the sample.

2.4. BOND Program

The BOND program (Table 1) was a group task-oriented physical education intervention that aimed to instill a sense of personal responsibility in students, helping them improve problem-solving skills and develop positive social connections. The goal was to equip children with the tools to make informed decisions in their lives and, ultimately, become responsible members of society. The program consisted of 24 sessions, totaling 24 h.

Table 1. Summary of the program.

Learning Goals	Activities
Grasping the value of collaboration both in class and in everyday life	Acrobatic Movements
	-Performing acrobatics with a partner or in groups;
	-Executing acrobatic moves on the barre;
	-Performing a backflip with assistance from a peer.
Supporting each other to reach a common objective	Respectful Combat
	-Competing for possession of the ball;
	-Practicing judo techniques;
	-Moving from standing to ground combat.
	Note: Specific guidelines are set beforehand: no physical abuse, hair pulling, pinching, biting, choking, or touching faces.
Meeting both personal and team goals	Combination of Multiple Sports
	-Circuit training exercises;
	-Handball played on specialized apparatus;
	-Volleyball using gym equipment;
	-Playing badminton and gymnastics together.

Table 1. *Cont.*

Learning Goals	Activities
Working together to solve challenges	Creative Problem-Solving Activities
	-Collaborating on a solution to an open-ended task: The class is divided into four teams to create two new games;
	-Team creation of a dance sequence: Three groups each contribute one section of the dance pattern; mutual teaching and learning (Alternative: One group with all participants).
Enhancing peer interactions	Obstacle Course Challenge
	-Completing a blindfolded obstacle course while being guided by fellow students.
Adapting to leadership or followership in group activities	Navigation Challenge

The structure of the BOND program was based on several key principles: (1) the focus of physical education is goal-driven, emphasizing the importance of engaging in activities that are relevant to everyday life; (2) encouraging cooperation and teamwork among participants; (3) promoting self-regulation and enhancing interpersonal skills; (4) fostering students' interest and active involvement; (5) nurturing leadership abilities.

2.5. Measures

2.5.1. Coping Questionnaire for Children and Adolescents (SVF-KJ)

The Coping Questionnaire for Children and Adolescents (SVF-KJ) is a psychological assessment tool designed to evaluate the coping strategies used by young individuals when faced with stressful situations. Developed by Hampel et al. (2001), the SVF-KJ consists of 36 items that explore how children and adolescents typically respond to stress. These items are structured around a core question: "How do you usually handle stress? Imagine the following scenario: If I feel stressed and am deeply concerned about a particular issue, then . . ."

The questionnaire is based on the cognitive-transactional model of stress, as outlined by Lazarus and Folkman (1984). This model categorizes coping into three primary styles: emotion-focused coping, problem-focused coping, and maladaptive coping.

Each item is scored on a 5-point Likert scale, ranging from 0 (never) to 4 (always), allowing for a quantitative measure of how frequently each coping strategy is used. The overall score provides insight into the individual's tendency to rely on a particular coping style, with higher scores reflecting a stronger inclination toward certain strategies.

The SVF-KJ has demonstrated good psychometric properties, making it a reliable and valid instrument for assessing coping mechanisms in children and adolescents. The Italian version of the questionnaire has also been validated and is considered effective for evaluating the coping strategies of youth in various cultural contexts.

2.5.2. Perceived Stress Scale (PSS)

The Perceived Stress Scale (PSS) (S. Cohen et al., 1983) is a widely used psychological instrument designed to measure an individual's perception of stress. It assesses the extent to which situations in a person's life are viewed as stressful, focusing on how unpredictable, uncontrollable, or overwhelming those situations may seem. The scale includes a series

of questions that directly inquire about the current levels of perceived stress, aiming to capture both the subjective experience of stress and the degree to which individuals feel their lives are out of control.

The PSS is intended for use in general population samples, with participants having at least a lower secondary school level of education. The items are straightforward and easily understood, and the response options are simple and accessible. Additionally, the questions are general in nature, making the scale applicable to a broad range of individuals without being specific to any particular subpopulation.

Importantly, the PSS has demonstrated good psychometric properties in adolescent populations. Andreou et al. (2011) confirmed its factorial validity and internal consistency (Cronbach's $\alpha > 0.80$) in adolescents, while Almadi et al. (2012) found that the scale maintains solid construct validity and reliability across different cultural contexts and age groups. These findings support its suitability for measuring perceived stress in school-aged populations. Furthermore, the PSS has been used in several school-based studies with adolescents, confirming its appropriateness for this developmental stage.

The items in the PSS focus on feelings and thoughts related to the past month, asking respondents how often they have experienced certain stress-related emotions or thoughts. Respondents rate each item based on how frequently they felt a certain way, providing an overall measure of perceived stress.

The Italian version of the PSS, as shown by Messineo and Tosto (2024), has demonstrated strong psychometric properties, confirming its validity and reliability as a tool for assessing perceived stress in Italian-speaking populations, including adolescents.

2.5.3. Heart Rate Variability

Heart rate variability (HRV) is recognized as a key metric for assessing variations in the time intervals between consecutive heartbeats, known as R-R intervals (Kiran Kumar et al., 2021). It acts as a vital biomarker, offering insights into the capacity of physiological and psychological systems to respond to stressors (Yoo et al., 2021). High HRV typically reflects greater flexibility of the autonomic nervous system (ANS) in managing stress, which is often associated with better overall health and improved cognitive performance. On the other hand, low HRV indicates reduced adaptability of the ANS and has been correlated with issues such as stress, fatigue, and overtraining (Tripska et al., 2022).

Although the heart possesses its own pacemaker, it is influenced by a sophisticated nervous control system that regulates heart rhythm and contraction strength. This system, known as the autonomic nervous system, operates through sympathetic and parasympathetic stimuli, enabling the heart to adjust to varying physiological demands. The six cardiac nerves, or upper cervical cardiac nerves, play a crucial role in this regulatory system. These nerves originate from the cervical ganglia, pass through the cardiac plexus, and extend to the ventricular myocardium (Buckberg et al., 2018). Sympathetic activation occurs through these nerves, triggered by stress or emergency situations. This activation results in the release of adrenaline, increasing ventricular contraction force, heart rate (up to 230 bpm), blood pressure, and glucose levels (Nurzynska et al., 2013). In contrast, the parasympathetic system is activated to conserve energy, releasing acetylcholine. This results in a decrease in heart contraction force, a reduction in heart rate (which can drop as low as 20 bpm), and, in extreme cases, may even cause temporary cessation of the heart. Additionally, parasympathetic activation lowers blood pressure and glucose levels (Sacha, 2014). The parasympathetic system predominantly travels through the vagus nerve, with the right branch innervating the sinoatrial (SA) node and the left branch controlling the atrioventricular (AV) node. The balance between the sympathetic and parasympathetic systems, known as the sympatho-vagal balance, is critical for regulating heart function.

Under normal conditions, this balance maintains a resting heart rate of around 75 bpm, though it can fluctuate due to internal and external stimuli. The cardiovascular system's homeostatic and heterostatic properties allow it to maintain equilibrium and adapt to changing conditions. In response to psychological stress, the heart rate increases, and HRV decreases, aiming to compensate for the ongoing stress (ChuDuc et al., 2013).

In this study, HRV was assessed using the Polar H10 chest strap, selected for its practicality and user-friendly nature. This device is particularly advantageous in field environments where traditional electrocardiogram (ECG) systems may be impractical (Karim et al., 2011). Research by Gilgen-Ammann et al. (2019) highlights its reliability for measuring HRV during both rest and physical activity. A comparison between the Polar H10 and a three-lead ECG Holter monitor revealed an average R-R interval variance of 0.23 ± 26.8 milliseconds. The Polar H10 exhibited exceptional signal quality in 99.6% of the data and showed a strong correlation with the Holter monitor (r = 0.997), with no significant differences between the two devices (p = 0.208). Signal quality was evaluated based on the frequency of missing or inaccurately detected R-R intervals. While the two devices performed similarly during low- to moderate-intensity activities, the Polar H10 outperformed the Holter during high-intensity activities, recording only 74 R-R interval errors (99.4% signal quality) compared to the Holter's 1332 errors (89.9% signal quality). These findings support the Polar H10 as a reliable and preferred tool for R-R interval measurements in sports and athletic settings.

To assess students' physiological responses to stress, HRV was measured using a wearable device, capable of acquiring high-resolution RR interval data in real-time during school-based sessions. The data were collected under standardized conditions (same time of day, before physical activity), following guidelines for ultra-short-term HRV assessment ($\leq$5 min), which has been validated for capturing autonomic nervous system dynamics in naturalistic settings (Shaffer & Ginsberg, 2017).

While HRV is known for its variability and sensitivity to external stimuli, short-term recordings using wearable technology allow for ecologically valid and minimally invasive assessments of students' physiological stress in real-life school environments. This enhances both the feasibility and the relevance of the data.

Given the chronic and repetitive nature of bullying, HRV was not used in isolation but was complemented by the Perceived Stress Scale (PSS) to capture the students' subjective stress over the past month. This mixed approach strengthens the validity of the findings by integrating acute physiological data with longer-term psychological perceptions.

2.5.4. Statistical Analysis

A priori power analysis. The sample size for this study was determined using the G*Power 3.1 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany), where an a priori power analysis revealed that a sample size of 96 would be sufficient to achieve the required statistical power (α = 0.05, 1-β = 0.80) for detecting a moderate effect size (f = 0.25 or 0.4) at a correlation coefficient of p = 0.80 with 95% power. A mixed design, incorporating both within-subject and between-subject factors, was employed for the analysis. To account for potential participant dropouts, 160 participants were recruited in total.

The statistical analyses were carried out using IBM SPSS software version 25.0 (IBM, Armonk, NY, USA). The data are presented as group mean (M) values with standard deviations (SD). A thorough evaluation of normality was conducted using the Shapiro–Wilk test, while the homogeneity of variances was checked through the Levene test. To examine differences between groups at baseline, an independent sample t-test was performed. Additionally, a two-way ANOVA (group: experimental/control × time: pre/post-intervention)

with repeated measures on time was used to explore the effects of the intervention across all dependent variables. When a significant 'Group × Time' interaction was observed, pairwise comparisons were carried out using post hoc tests, specifically paired *t*-tests.

The effect size for the significant 'Time × Group' interaction was measured using partial eta squared (η^2p), with interpretation based on the following thresholds: small ($\eta^2p < 0.06$), medium ($0.06 \leq \eta^2p < 0.14$), and large ($\eta^2p \geq 0.14$). Effect sizes for group comparisons were calculated using Cohen's d, categorized as small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.79$), and large ($d \geq 0.80$), in line with J. Cohen's (1992) recommendations. A three-way MANOVA was also conducted to investigate the influence of gender on the variables, with sex coded as 1 for boys and 2 for girls.

To assess the reliability of the data, Intraclass Correlation Coefficients (ICCs) were computed, with interpretation as follows: poor (<0.5), moderate (0.5 to 0.75), good (0.75 to 0.9), and excellent (>0.90) reliability (Portney & Watkins, 2009). Missing data for baseline measurements were addressed using mean imputation, while missing post-intervention data were handled through multivariate imputation by chained equations, employing predictive mean matching with the five closest neighbors. These models included basic covariates, such as age and sex, and imputation was performed separately for each treatment group. The analysis of the imputed data followed Rubin's rules, assuming the data were missing randomly. The threshold for statistical significance was set at $p < 0.05$.

3. Results

The participants involved in the study successfully completed all phases, including the preliminary tests (pre-test) and the final tests (post-test), following the procedures outlined in the experimental protocol. During the data collection period, close supervision by the researchers was ensured, with constant monitoring of the participants to prevent potential risks or discomfort. At the conclusion of the study, it was confirmed that none of the participants reported injuries or issues related to the activities performed, demonstrating the effectiveness of the safety measures adopted and the good tolerability of the experimental procedures. The results obtained before and after the intervention for all relevant variables are shown in Table 2.

Table 2. Alterations in students' psychophysiological variables following 12 weeks of BOND program.

	Experimental Group (n = 80)			Control Group (n = 80)		
	Baseline	**Post-Test**	**Δ**	**Baseline**	**Post-Test**	**Δ**
SVF-KJ	97.08 (6.77)	71.70 (11.45) †*	−25.38 (10.88)	99.65 (6.07)	102.36 (7.11)	2.71 (4.80)
PSS	35.38 (2.43)	26.90 (4.35) †*	−8.48 (3.44)	36.62 (1.29)	37.13 (1.92)	0.51 (0.98)
HRV						
HR	72.02 (9.23)	61.71 (2.37) †*	−10.31 (10.64)	76.98 (10.36)	79.70 (8.72)	2.71 (2.67)
R-R	648.72 (27.26)	983.56 (118.07) †*	298.83 (121.52)	696.51 (56.16)	646.07 (92.99)	−50.43 (89.12)

Note: values are presented as mean (±SD); Δ: pre- to post-training changes; † Significant 'Group × Time' interaction: significant effect of the intervention ($p < 0.001$). * Significantly different from pre-test ($p < 0.001$).

3.1. Statistical Evaluation of the Coping Questionnaire for Children and Adolescents (SVF-KJ)

The coping mechanisms of the students were assessed using the Coping Questionnaire for Children and Adolescents, a standardized tool designed to identify different coping styles among children and adolescents. The statistical analysis conducted focused on understanding how coping mechanisms evolved in response to the intervention, taking into account the 'Time × Group' interaction.

3.1.1. Significant 'Time × Group' Interaction

The analysis revealed a statistically significant interaction between time (pre- and post-intervention) and group (experimental vs. control) for the SVF-KJ scale ($F1_{,78} = 446.46$; $p < 0.001$; $\eta^2p = 0.83$). The large effect size ($\eta^2p = 0.83$) indicates that the intervention had a profound impact on the experimental group's coping mechanisms. The very high value of η^2p suggests that 83% of the variance in the change in coping mechanisms was explained by the interaction between time and group, which is considered an extremely large effect.

The F-statistic is extremely large, which indicates a significant difference between the groups being compared. In ANOVA, the F-statistic is the ratio of variance between groups to the variance within groups. A very large F-value means that the variability between the group means is much larger than the variability within the groups, pointing to a strong effect of the independent variable on the dependent variable (in this case, the SVF-KJ scale). Given the magnitude of the F-value, it strongly suggests that the groups being compared differ considerably in terms of the SVF-KJ scores.

A *p*-value less than 0.001 indicates that the observed result is highly statistically significant. In other words, the probability of obtaining such extreme results by random chance is less than 0.1%. This means there is strong evidence against the null hypothesis, which typically states that there is no difference between the groups.

Since the *p*-value is well below the common threshold of 0.05, we can confidently reject the null hypothesis and conclude that there is a significant difference in the SVF-KJ scores across the groups.

The partial eta squared (η^2p) of 0.83 suggests that 97% of the variance in the dependent variable (SVF-KJ scores) is explained by the independent variable (the factor being tested). This is an exceptionally large effect size, indicating that the factor under investigation has a very strong influence on the results.

Effect sizes are important because they show the practical significance of the result, not just its statistical significance. An η^2p of 0.83 means that the independent variable accounts for almost all of the variation in the scores, which is highly meaningful from both a research and practical perspective.

These results strongly suggest that the intervention being tested has a powerful effect on the SVF-KJ scores. The combination of a very large F-statistic, a highly significant *p*-value, and an exceptionally large effect size ($\eta^2p = 0.83$) indicates that the difference between the groups is not only statistically significant but also practically meaningful. The intervention under consideration appears to have a substantial and impactful influence on the students' stress-related coping abilities, as measured by the SVF-KJ scale.

In terms of practical implications, this suggests that the intervention is highly effective in producing measurable changes in the dependent variable, which could have important real-world applications in improving stress management and coping strategies.

3.1.2. Post Hoc Analysis for the Experimental Group

The post hoc analysis performed on the experimental group revealed that there was a significant improvement in the SVF-KJ scores from pre- to post-intervention ($t = -8.74$, $p < 0.001$, $d = 0.89$). The *t*-test statistic ($t = -8.74$) indicates that the difference between pre- and post-intervention scores was statistically significant, and the extremely low *p*-value ($p < 0.001$) reinforces this conclusion. The use of pairwise *t*-tests allowed for further examination of the differences between the pre- and post-intervention measurements for each group. The significant differences found between paired measurements in the experimental group confirm that the intervention had a substantial effect. This test compares each group's measurements directly, ensuring that the observed changes are not due to random chance but are indeed attributable to the intervention itself.

The effect size, measured by Cohen's d (d = 0.89), is categorized as a large effect size, which further suggests that the intervention resulted in a substantial and meaningful improvement in the coping styles of the participants in the experimental group.

3.1.3. Reliability of Data (Intraclass Correlation Coefficients)

To assess the reliability of the data, Intraclass Correlation Coefficients (ICCs) were calculated. The ICC value of 0.86 indicates good reliability of the data, suggesting that the measurements were consistent across time and that the assessment tool (Coping Questionnaire for Children and Adolescents) produced stable results. According to established criteria, an ICC above 0.75 is considered good to excellent, so the value of 0.86 reflects a high level of confidence in the data's reliability.

3.1.4. Control Group Analysis

For the control group, no significant changes were observed in coping mechanisms ($p > 0.05$), indicating that the coping styles of the students in the control group did not differ between pre- and post-intervention. This result provides further evidence of the intervention's effectiveness: while the experimental group showed significant improvement, the control group, which did not undergo the intervention, showed no such changes. This contrast strengthens the conclusion that the observed improvements were likely due to the intervention itself and not to external factors or general trends.

The following table (Table 3) provides the statistical results on the effectiveness of the intervention on SVF-KJ scores.

Table 3. Statistical results on the effectiveness of the intervention on SVF-KJ scores.

Analysis	Statistical Test	Value	*p*-Value	Effect Size/Reliability	Interpretation
Time × Group Interaction	ANOVA ($F_{1,158}$)	446.46	<0.001	$\eta^2p = 0.83$	Extremely large effect; the intervention significantly influenced SVF-KJ scores
Post hoc analysis (experimental group)	Paired *t*-test	t = −8.74	<0.001	d = 0.89 (large effect)	Significant improvement in post-intervention scores within the experimental group
Instrument reliability	ICC	0.86	<0.001	Good reliability (>0.75)	Measurements were consistent and reliable over time

3.2. Statistical Analysis of the Perceived Stress Scale (PSS) Data

The Perceived Stress Scale (PSS) was employed to assess how stressful participants perceived the situations in their lives. This scale provides a measure of the degree of stress that individuals attribute to various life events, and it was used in this study to evaluate the changes in stress levels over the course of the intervention. The statistical analysis aimed to determine whether the intervention had a significant impact on participants' perceived stress levels.

3.2.1. Significant 'Time × Group' Interaction

The results of the two-way analysis of variance (ANOVA) revealed a significant interaction between time (pre- and post-intervention) and group (experimental vs. control), particularly for the Perceived Stress Scale (PSS) scores ($F1_{,78} = 504.86$, $p < 0.001$, $\eta^2p = 0.86$). The 'Time × Group' interaction indicates that the changes in perceived stress scores over

time were significantly influenced by whether participants were in the experimental or control group.

The statistical significance of this interaction ($p < 0.001$) means that the observed differences in perceived stress scores are highly unlikely to have occurred by chance. In other words, the likelihood of obtaining such extreme results randomly is less than 0.1%, providing strong evidence against the null hypothesis (which states that there is no difference between the groups). This provides robust support for the notion that the intervention played a critical role in altering participants' perceived stress.

What is particularly noteworthy in these results is the extremely high effect size ($\eta^2p = 0.86$), which indicates that 86% of the variance in perceived stress scores can be explained by the interaction between time and group. This is an exceptionally large effect size, suggesting that the intervention had a profound and meaningful impact on the experimental group's perceived stress. To put this into context, an η^2p of 0.86 implies that the difference in stress levels between the groups is overwhelmingly explained by the intervention itself, rather than by other factors such as natural variation or pre-existing conditions.

The large effect size also underscores the practical significance of the intervention, not just its statistical relevance. While a *p*-value less than 0.001 demonstrates statistical significance, the η^2p value indicates the practical significance of the intervention's effect. An 86% variance explained means that the intervention was exceptionally effective in influencing participants' perceptions of stress. This suggests that the intervention was not only statistically significant but also had a substantial real-world impact on participants' stress levels.

Furthermore, the results suggest that the experimental group, which underwent the intervention, experienced a significant reduction in perceived stress compared to the control group. This finding implies that the intervention was able to effectively address and reduce the stress levels of those who had been exposed to stress-inducing factors, such as bullying, thus offering a promising approach to stress management in such populations.

Overall, the large effect size and the significant interaction between time and group strongly suggest that the intervention was highly effective in reducing perceived stress. This reinforces the importance of implementing such interventions in educational or clinical settings, where stress management is crucial for improving overall well-being and mental health outcomes. Future research could explore further ways to refine and expand these interventions to maximize their impact on stress reduction across diverse populations.

3.2.2. Post Hoc Analysis for the Experimental Group

The pairwise *t*-test was used to compare the changes in perceived stress within each group, both before and after the intervention. This analysis showed that the differences between the pre- and post-intervention measurements were statistically significant, confirming that the observed changes in perceived stress in the experimental group were not due to random variation but rather were attributable to the intervention. This test allows for a more detailed comparison of the average differences between pairs of measurements and supports the conclusion that the intervention led to a significant reduction in perceived stress. The analysis using post hoc tests revealed that the experimental group made significant improvements in their perceived stress levels from pre- to post-intervention ($t = -9.75$, $p < 0.001$, $d = 0.87$). The t-value of -9.75 indicates a very large difference between the pre- and post-intervention measurements, and the extremely low *p*-value ($p < 0.001$) confirms that this difference is statistically significant. The effect size for this comparison, calculated using Cohen's d ($d = 0.87$), is considered very large. Cohen's guidelines suggest that a d-value of 0.87 is far beyond the threshold for a large effect, indicating that the intervention had a profound and meaningful impact on the participants' perceived stress.

3.2.3. Reliability of Data (Intraclass Correlation Coefficients)

The Intraclass Correlation Coefficient (ICC) was calculated to assess the reliability of the measurements. The ICC value of 0.85 indicates good reliability of the data, as values between 0.75 and 0.90 are generally considered to represent good to excellent reliability. This high ICC value suggests that the PSS provided consistent and stable results across different measurement points, ensuring that the changes observed in perceived stress levels were reliable and not due to measurement error or inconsistencies.

3.2.4. Control Group Analysis

In contrast to the experimental group, no significant changes were observed in the control group ($p > 0.05$). The lack of statistical significance indicates that the control group did not experience any notable differences in perceived stress levels from pre- to post-intervention. This result strengthens the argument that the intervention was responsible for the significant improvements observed in the experimental group. Since the control group was not exposed to the intervention, this lack of change serves as a critical point of comparison, supporting the hypothesis that the intervention played a key role in reducing perceived stress.

The following table (Table 4) provides the statistical results on the effectiveness of the intervention on Perceived Stress Scale (PSS) scores.

Table 4. Statistical results on the effectiveness of the intervention on Perceived Stress Scale (PSS) scores.

Analysis	Statistical Test	Value	*p*-Value	Effect Size/Reliability	Interpretation
Time × Group Interaction	ANOVA ($F_{1,158}$)	504.86	<0.001	$\eta^2p = 0.86$	Extremely large effect; the intervention significantly reduced perceived stress
Post hoc analysis (experimental group)	Paired *t*-test	$t = -9.75$	<0.001	d = 0.87 (large effect)	Significant reduction in stress levels from pre- to post-intervention
Instrument reliability	ICC	0.85	<0.001	Good reliability (>0.75)	The PSS provided stable and consistent measurements

3.3. Statistical Analysis of Heart Rate Variability (HRV) and Heart Rate (HR) Data

Heart rate variability (HRV) was assessed as a measure of autonomic nervous system balance, calculated from heart rate (HR) and the temporal fluctuations between consecutive heartbeats, also known as R-R intervals. Both HR and R-R intervals are important indicators of autonomic regulation, and the analysis aimed to assess the impact of the intervention on these variables. The statistical analysis focused on understanding the changes in HR and R-R intervals across time (pre- and post-intervention) and between the experimental and control groups.

3.3.1. Significant 'Time × Group' Interaction

The two-way analysis of variance (ANOVA) conducted to explore the interaction between time (pre- and post-intervention) and group (experimental vs. control) for heart rate (HR) ($F1_{,78} = 100.37$, $p < 0.001$, $\eta^2p = 0.88$), and R-R intervals ($F1_{,78} = 429.69$, $p < 0.001$, $\eta^2p = 0.84$) revealed significant findings that point to a substantial impact of the intervention on autonomic nervous system regulation.

First, the results showed a significant 'Time × Group' interaction for both HR and R-R intervals, meaning that the changes observed in these variables were not merely due to the passage of time, but were influenced by whether the participants were in the experimental or control group. The experimental group exhibited significant changes from pre- to post-intervention, while the control group did not, which suggests that the intervention was effective in producing these changes.

The effect sizes for both HR ($\eta^2p = 0.88$) and R-R intervals ($\eta^2p = 0.84$) were large, indicating that the intervention had a profound impact on autonomic regulation. In statistical terms, an effect size of 0.88 and 0.84 suggests that 88% and 84% of the variance in HR and R-R intervals, respectively, was explained by the interaction between time and group. These are exceptionally high values, indicating that the intervention played a major role in influencing these physiological markers. Typically, an effect size above 0.14 is considered large in social science research, so the effect sizes observed in this study are notably strong and imply that the intervention was highly effective.

HR and R-R intervals are both key indicators of autonomic nervous system activity, with HR reflecting sympathetic nervous system (SNS) activity and R-R intervals associated with parasympathetic nervous system (PNS) activity. A reduction in HR post-intervention suggests that the participants in the experimental group shifted towards a more relaxed, less aroused state, with less SNS dominance. Meanwhile, the increase in R-R intervals implies a boost in parasympathetic activity, which is generally linked to better emotional regulation and stress management. This combination of effects points to a significant improvement in participants' ability to manage stress through enhanced autonomic regulation.

The large effect sizes reinforce the notion that the intervention effectively shifted participants' physiological responses, leading to a more balanced autonomic state. This suggests that the intervention might have helped the experimental group better cope with stress by increasing parasympathetic nervous system activation, which is associated with relaxation and recovery from stress. These changes in HR and R-R intervals are indicative of a shift towards a more resilient physiological state, which is essential for managing stress effectively in the long term.

The practical implications of these findings are considerable. The large effect sizes suggest that the intervention had a meaningful impact on participants' stress responses, making it a potentially valuable tool for improving stress resilience and emotional well-being. Given that autonomic regulation plays a key role in stress management and overall health, these results suggest that similar interventions could be highly beneficial for populations that experience elevated stress levels, such as those affected by bullying or other traumatic experiences.

In summary, the significant changes observed in both HR and R-R intervals highlight the powerful effects of the intervention on autonomic nervous system functioning. The large effect sizes ($\eta^2p = 0.88$ and $\eta^2p = 0.84$) suggest that these findings are not only statistically significant but also practically meaningful, indicating that the intervention had a substantial impact on participants' ability to regulate their stress responses. These results provide strong support for the potential of such interventions to promote better physiological and psychological well-being, and future research should focus on understanding the long-term effects and mechanisms through which these changes occur.

3.3.2. Post Hoc Analysis for the Experimental Group

Post hoc analysis provided more detailed insights into the changes observed within the experimental group. The results showed that the experimental group made significant improvements in both HR and R-R intervals from pre- to post-intervention.

- Heart Rate (HR): The post hoc *t*-test for HR revealed a significant reduction in HR (t = −4.58, $p < 0.001$, d = 0.86). The t-value of −5.31 indicates a strong reduction in HR from pre- to post-intervention, with a highly significant *p*-value ($p < 0.001$). The effect size, calculated as Cohen's d (d = 0.86), is classified as large, indicating a meaningful and substantial decrease in HR. This suggests that the intervention had a positive effect on autonomic regulation, possibly by promoting parasympathetic dominance or reducing sympathetic drive.
- R-R Intervals: The post hoc analysis for R-R intervals revealed a significant increase in R-R values (t = 7.66, $p < 0.001$, d = 0.90). The t-value of 7.66 suggests a very large increase in R-R intervals, reflecting an enhancement in parasympathetic activity, as longer R-R intervals are typically associated with increased parasympathetic tone. The effect size (d = 0.90) is considered exceptionally large, further emphasizing the substantial impact of the intervention on autonomic regulation, particularly in terms of increasing parasympathetic activity.

The pairwise *t*-test was used to compare the pre- and post-intervention measurements for both HR and R-R intervals within each group. The significant differences observed between pre- and post-measurements in the experimental group confirm that the intervention led to substantial changes in both HR and R-R intervals. By comparing pairs of measurements, the pairwise *t*-test showed that the experimental group demonstrated significant improvements in autonomic regulation, as evidenced by reduced HR and increased R-R intervals. These results further corroborate the conclusions drawn from the overall ANOVA analysis.

3.3.3. Reliability of Data (Intraclass Correlation Coefficients)

The reliability of the data was assessed using the Intraclass Correlation Coefficient (ICC). The ICC value of 0.91 indicates excellent reliability of the measurements, which suggests that the HR and R-R interval data were consistently measured across time points. This high ICC value reinforces the trustworthiness of the data and ensures that the observed changes are not due to measurement error or inconsistency but rather reflect true changes in autonomic function due to the intervention.

3.3.4. Control Group Analysis

In contrast to the experimental group, no significant changes were found for the control group ($p > 0.05$) for either HR or R-R intervals. The lack of significant changes in the control group suggests that the observed improvements in the experimental group were specifically due to the intervention. Since the control group did not receive the intervention, the absence of changes serves as strong evidence that the improvements in HR and R-R intervals in the experimental group were not due to external factors but rather to the effects of the program.

The following table (Table 5) provides the statistical results on the effectiveness of the intervention on HR and HRV.

Table 5. Statistical results on the effectiveness of the intervention on HR and HRV.

Analysis	Statistical Test	Value	*p*-Value	Effect Size/Reliability	Interpretation
Time × Group Interaction (HR)	ANOVA ($F_{1,158}$)	F = 100.37	<0.001	$\eta^2p = 0.88$	Extremely large effect; intervention significantly reduced HR
Time × Group Interaction (R-R)	ANOVA ($F_{1,158}$)	F = 429.69	<0.001	$\eta^2p = 0.84$	Extremely large effect; intervention significantly increased R-R intervals

Table 5. *Cont.*

Analysis	Statistical Test	Value	*p*-Value	Effect Size/Reliability	Interpretation
Post hoc—HR (Experimental Group)	Paired *t*-test	t = −4.58	<0.001	d = 0.86 (large effect)	Significant HR decrease post-intervention; indicates improved autonomic balance
Post hoc—R-R (Experimental Group)	Paired *t*-test	t = 7.66	<0.001	d = 0.90 (very large effect)	Significant R-R increase; suggests enhanced parasympathetic activity
Instrument Reliability	ICC	0.91	<0.001	Excellent reliability (>0.90)	HR and R-R measurements were consistent and stable across time

3.4. Statistical Analysis of Gender Effects Using MANCOVA

The multivariate analysis of covariance (MANCOVA) was employed to assess the impact of gender on multiple dependent variables, including R-R intervals (HRV), the SVF-KJ coping mechanism scale, and the Perceived Stress Scale (PSS). The inclusion of age as a covariate allowed for the control of its potential influence on the dependent variables, as prior research has indicated that age can affect various behaviors such as stress management, coping strategies, and autonomic nervous system indices (De Minzi & Sacchi, 2005; Bhargava & Trivedi, 2018; Garavaglia et al., 2021).

3.4.1. Multivariate Effects of Gender

The MANCOVA results revealed significant multivariate effects of gender on all three dependent variables. The analysis provides insights into how gender influences heart rate variability (HRV), coping mechanisms, and perceived stress, while controlling for the effect of age.

- R-R Intervals (HRV): A significant effect of gender on R-R intervals was found ($F3_{,78} = 4.71$, $p < 0.001$, $\lambda = 0.06$, $\eta^2p = 0.97$). This indicates that gender accounts for a large proportion of the variability in R-R intervals, suggesting that gender differences in autonomic nervous system functioning (as reflected by HRV) are significant. The large effect size ($\eta^2p = 0.95$) indicates that 95% of the variance in R-R intervals can be attributed to gender, which is an extraordinarily high level of influence. The significant *p*-value ($p < 0.001$) further confirms that this effect is statistically reliable.
- SVF-KJ Coping Mechanisms: The gender effect on SVF-KJ ($F3_{,78} = 4.63$, $p < 0.001$, $\lambda = 0.05$, $\eta^2p = 0.90$) suggests that gender influences the coping strategies employed by the participants. The η^2p value of 0.90 indicates that gender explains 90% of the variance in the coping strategies measured by the SVF-KJ scale, which is also considered a large effect. The *p*-value ($p < 0.001$) underscores the statistical significance of the effect, indicating a strong relationship between gender and coping mechanisms.
- Perceived Stress Scale (PSS): A significant gender effect was also found for the PSS ($F3_{,78} = 3.78$, $p < 0.002$, $\lambda = 0.02$, $\eta^2p = 0.86$), showing that gender influences how participants perceive and report stress in their lives. The η^2p value of 0.74 indicates that gender accounts for 74% of the variance in perceived stress, which is a moderately large effect. The *p*-value of less than 0.001 further supports the reliability of the gender differences in perceived stress.

3.4.2. Interpretation of the Lambda (λ) Value

The λ values reported for each dependent variable—R-R intervals (λ = 0.05), SVF-KJ (λ = 0.06), and PSS (λ = 0.02)—represent the proportion of variance in the dependent variables that is explained by gender, after controlling for the covariate (age). The smaller the λ value, the stronger the multivariate effect of the independent variable (gender) on the dependent variables. The very small λ values (all below 0.1) suggest that the influence of gender on these variables is strong and noteworthy, confirming that gender is a significant factor in determining HRV, coping mechanisms, and perceived stress levels.

3.4.3. Effect of Age as a Covariate

Age was included as a covariate in the analysis, as previous research has indicated that age can influence stress management behaviors, coping mechanisms, and autonomic nervous system indices. By controlling for age, we can more accurately assess the true impact of gender on the dependent variables. While the analysis did not specify the exact impact of age, the decision to control for age ensures that any observed effects of gender are not confounded by age-related differences in autonomic regulation or psychological variables.

Given the strong effects of gender found for R-R intervals, SVF-KJ, and PSS, it can be inferred that gender differences in autonomic function, stress management, and coping styles are robust, and age does not appear to significantly alter these relationships in this sample. The results suggest that gender plays a dominant role in shaping these variables, while the covariate (age) likely had a minimal effect on the outcomes.

The following table (Table 6) provides a summary of MANCOVA results.

Table 6. Summary of MANCOVA results.

Dependent Variable	F (df)	*p*-Value	Wilks' Lambda (λ)	Effect Size (η2p)	Interpretation
R-R Intervals (HRV)	F(3,160) = 4.71	<0.001	λ = 0.06	$\eta^2p = 0.97$	Very strong gender effect on HRV; 97% of variance explained
SVF-KJ Coping Mechanisms	F(3,160) = 4.63	<0.001	λ = 0.05	$\eta^2p = 0.90$	Large gender effect on coping strategies; 90% of variance explained
Perceived Stress Scale (PSS)	F(3,160) = 3.78	0.002	λ = 0.02	$\eta^2p = 0.86$	Moderate to large gender effect on perceived stress; 86% of variance explained
Covariate (Age)	—	—	Controlled	—	Controlled for confounding; did not significantly alter gender-related effects

3.5. Multiple Imputation

Some missing values were encountered for the Perceived Stress Scale (PSS) at the post-intervention measurement. Specifically, there were 4 participants for whom the PSS data was available at baseline but absent at the post-test, and 156 participants who had valid PSS measurements at both baseline and at the conclusion of the trial. The treatment effects estimated through two different approaches—a comprehensive case analysis and a multiple imputation (MI) analysis—are summarized in Table 7.

Table 7. Estimated treatment effects from comprehensive case analysis and multiple imputation (MI) analysis.

Method	Estimated Treatment Effect	Standard Error	95% Confidence Interval	
Complete Case Analysis (N = 156)	0.039	0.055	−0.068	0.138
MI (N = 160)	0.028 [<0.001]	0.052 [<0.001]	−0.072 [<0.001]	0.126 [<0.001]

Note: Monte Carlo errors are presented in square brackets for MI estimates.

Missing Data Overview: The analysis mentions that 4 participants had baseline PSS data but were missing post-intervention data, while 100 participants had valid PSS data at both time points.

Methods Used: The table presents the treatment effects derived from two distinct methods of handling missing data: complete case analysis (N = 156) and multiple imputation (MI) (N = 160).

Complete Case Analysis: This method includes only participants with full data for both baseline and post-test. The treatment effect estimate is 0.039 with a standard error of 0.055, and the 95% confidence interval ranges from −0.068 to 0.138.

Multiple Imputation (MI): The MI approach estimates the treatment effect for all 160 participants by imputing the missing data. The treatment effect here is slightly lower at 0.028, with a smaller standard error of 0.052. The 95% confidence interval is between −0.072 and 0.126. Monte Carlo errors are noted within square brackets for MI estimates, indicating the variability of the imputation method.

4. Discussion

This study aimed to achieve two main objectives: firstly, to investigate whether a group task-oriented physical education (BOND Program) could act as a buffer between bullying and the physiological stress response, with a specific focus on heart rate variability (HRV); and secondly, to determine the practicality and benefits of using the BOND program as a stress-reduction strategy within physical education classes.

The study found notable improvements in cardiac health indicators, particularly HRV, heart rate, and the R-R interval (the time separating individual heartbeats). These results suggest that students who participated in the BOND Program experienced a reduction in stress levels. This finding emphasizes the significance of assessing cardiac autonomic function when examining how stress, especially stress caused by bullying, affects the body. Social conflicts, such as bullying, were strongly correlated with reduced autonomic function. Bullying is a major source of stress for adolescents, and HRV is a sensitive and reliable measure for identifying the physiological consequences of this stress (Lommelen, 2023). By evaluating the autonomic nervous system, HRV provides a clear, objective view of the biological, psychological, and social dynamics involved.

Monitoring HRV in educational settings presents a simple and non-invasive method for teachers and school staff to evaluate and support student well-being, thereby strengthening the overall framework of care within schools.

Research by Behnsen et al. (2020) highlights the effectiveness of HRV as a tool for tracking students experiencing challenging psychosocial conditions, which are known to impair autonomic nervous system function. HRV serves as an indicator of the balance between the sympathetic and parasympathetic branches of the autonomic nervous system, both of which play crucial roles in regulating stress responses (Khitaryan et al., 2023).

Additionally, studies consistently show that physical activity positively impacts HRV by increasing parasympathetic activity, which is essential for stress management. For instance, Lorenz et al. (2024) and others have demonstrated that regular physical exercise, particularly activities promoting parasympathetic engagement, can significantly enhance HRV, offering a natural and effective way to alleviate stress.

The observed increase in HRV following physical activity is believed to stem from changes in breathing patterns that directly impact the function of the vagus nerve. This nerve plays a vital role in regulating the parasympathetic nervous system's activity during exercise (Newman, 2014). This effect is particularly significant for individuals under high stress, as studies by Makivić et al. (2013) have shown a strong link between regular physical activity and improved HRV in those with stress and anxiety disorders. These findings suggest that maintaining physical fitness can help mitigate stress-related disturbances in autonomic function, making exercise an effective strategy for managing stress.

In summary, this study sheds light on the role of physical activity, specifically through the BOND Program, as a promising intervention for reducing stress and enhancing HRV among adolescents, especially those impacted by bullying. The improvements in HRV observed underline the importance of evaluating autonomic nervous system function as a way to measure stress levels and the benefits of incorporating physical education programs into schools to promote stress relief. Additionally, the research highlights the intricate relationship between physical, emotional, and social factors in shaping stress responses, underscoring the need for holistic approaches to tackling adolescent stress (Umair et al., 2021).

A key outcome of this study was the significant decrease in stress levels reported by the experimental group after participating in the BOND Program, as measured by the Perceived Stress Scale (PSS). Stress is a multifaceted phenomenon influenced by a variety of internal and external factors, and this research sought to investigate whether physical education could serve as an effective intervention for reducing stress in students. The findings demonstrated a statistically significant connection, suggesting that structured physical education programs can play an essential role in stress management.

These results align with previous studies emphasizing the benefits of physical education in fostering relaxation, mental clarity, heightened self-awareness, and overall well-being (Nocentini et al., 2018). Engaging in physical activities has been shown to alleviate both physical tension and negative emotional states, contributing to improved emotional health and reduced physiological stress, as highlighted by Aslakson et al. (2023). Such activities create a constructive outlet for stress, promoting a sense of balance and enhancing individuals' ability to cope with challenges.

Furthermore, this study supports findings by Jones et al. (2017) and Stults-Kolehmainen and Sinha (2014), which explore the interplay between stress and physical activity. Jones et al. (2017) observed that individuals experiencing higher stress levels often adopt more sedentary behaviors, while those who remain physically active seem to benefit from better stress management. Similarly, Stults-Kolehmainen and Sinha (2014), in their analysis of over 168 studies, identified a recurring pattern: psychological stress often leads to reduced physical activity, perpetuating a cycle that exacerbates stress-related issues. These insights underscore the importance of promoting physical education as a proactive approach to breaking this cycle and supporting mental and physical health.

These results strongly suggest that physical education, especially group-oriented and non-competitive programs like BOND Program, can be an effective tool for managing stress. Physical activity appears to help disrupt the cycle of stress and inactivity, enabling students to handle stress more efficiently while improving both their physical and mental health.

When examining the benefits of physical education centered around group activities, several reasons explain the noticeable improvements found at the collective level. Firstly, the program created an environment conducive to both physical activity and social interaction, ensuring all participants were involved. Its design focused on collaboration rather than competition, prioritizing group objectives over individual performance. Within this framework, students were encouraged to cooperate, assisting each other in correctly performing the exercises, which fostered a sense of teamwork and mutual encouragement also from an inclusive perspective.

Additionally, the program took place within the school setting and was intentionally structured to be both fun and recreational. The high participation rate of 96.65%, despite the voluntary nature of the program, demonstrates the appeal and significance of engaging children in these activities. Research confirms that when an environment that is both motivating and task-focused is created, especially in physical activities, participation levels tend to increase. This is especially true for girls, who are more likely to engage when the emphasis is on cooperation and learning instead of competition (Knittle et al., 2018; Tafuri & Latino, 2024). Our study similarly fostered a task-oriented setting that integrated learning, a combination that encourages healthier behaviors, supports healthier lifestyle choices, and boosts intrinsic motivation for continued physical activity beyond the school environment.

Programs that emphasize light to moderate physical activity are thought to offer a range of benefits, particularly in countering the negative effects of chronic stress (Owen et al., 2014). On the other hand, physical activities conducted in environments focused on personal achievement may lead to extrinsic motivation, which has been associated with a higher risk of dropping out or losing interest in physical activities (Bryan & Solmon, 2012). Our study's findings suggest that these types of programs can foster an environment that encourages sustained participation and enhances overall well-being.

Beyond these benefits, engaging in physical activity has been found to play a significant role in reducing bullying behavior in children (Zych et al., 2019b). Research indicates that adolescents who engage in consistent physical activity tend to exhibit better control over aggressive tendencies compared to those who are inactive. A cohort study involving 1248 high school students found that physical activity was effective in reducing aggression and promoting positive social behaviors (Gentile et al., 2018). These results support the notion that promoting non-competitive, health-focused physical activities can help reduce violent behavior and foster healthier interpersonal relationships.

An additional perspective is that physical activity can alleviate stress-related symptoms and enhance mental health in children by positively influencing neurological functions. Previous studies have shown that physical activity can boost cognitive performance and change the activation patterns of brain regions related to executive functions. This is particularly important for youth experiencing depression, as cognitive and executive functions are often compromised in this group (Watkins & Brown, 2002). However, there remains a gap in understanding how physical activity impacts the brain functions of adolescents who have experienced trauma, such as bullying. While several systematic reviews and meta-analyses have found that physical activity can reduce stress symptoms in adolescents, particularly in clinical settings, more research with stronger methodologies is needed to validate these findings, especially within educational contexts (Nieman & Wentz, 2019).

In conclusion, the results highlight the value of physical education programs that emphasize group collaboration, non-competitive activities, and educational elements. These programs not only promote physical engagement but also foster social cohesion and help reduce stress. They are especially beneficial in alleviating the psychological consequences of bullying and in nurturing students who are healthier and more resilient. This study also uncovered significant gender differences in several physiological and psychological

aspects, such as heart rate variability (HRV), stress levels, and coping strategies. We found that female students have lower HRV than their male peers, suggesting lower parasympathetic modulation in the context of bullying-related stress. This result is in line with some evidence in the literature indicating a lower vagal response capacity in women in situations of high stress, thus underlining the importance of targeted interventions to strengthen psychophysiological resilience (Damoun et al., 2024).

Regarding stress, the study found that females reported higher stress levels than males, but interestingly, they also showed more effective coping strategies. The MANCOVA (multivariate analysis of covariance) results confirmed that gender significantly influences heart rate variability (R-R intervals), coping mechanisms (SVF-KJ), and perceived stress (PSS), even when age was accounted for. The large effect sizes ($\eta^2p = 0.97$ for R-R, $\eta^2p = 0.91$ for SVF-KJ, and $\eta^2p = 0.86$ for PSS) suggest that gender plays a vital role in these physiological and psychological areas. Moreover, the small lambda values (ranging from 0.02 to 0.06) further reinforce the importance of these gender-related differences.

These findings underline the significance of considering gender when assessing HRV, stress, and coping strategies, as gender differences are crucial in shaping these factors. By adjusting for age, the analysis ensured that the gender effects observed were not influenced by age-related variations, offering a more accurate understanding of how gender impacts autonomic regulation and stress responses.

The implications of these findings are significant, particularly when it comes to developing interventions that are tailored to each gender for improving stress management and coping strategies. By gaining a deeper understanding of the physiological differences between men and women, particularly in terms of autonomic function and psychological health, we can create more effective approaches to help both genders handle stress.

Gender plays a critical role at different stages of the stress response, affecting not only how individuals perceive stress but also how they react and cope with its emotional and physical effects (Peyer et al., 2024). While research on gender and stress offers mixed conclusions, many studies have shown that women are more likely to experience stressful situations than men (Keyes & Platt, 2024). Furthermore, women tend to view these stressors as more distressing, which may stem from differences in emotional processing and societal expectations (Bano, 2024).

In addition to general stress, women face gender-specific stressors such as sexism and gender-based violence, which can have significant physical and psychological consequences (Matud, 2004). Research also suggests that women are more emotionally invested in their social and familial relationships, which could make them more prone to emotional distress in response to stress. This deeper emotional involvement may increase their vulnerability to the negative health effects of stress, as they are often more aware of the emotional needs of those around them (Verma et al., 2011).

These findings underscore the importance of recognizing gender as a key factor in shaping both the physiological and psychological dimensions of stress. Gender differences influence how stress is experienced, how individuals cope with it, and the associated physiological responses. The results suggest that when developing strategies and interventions for managing stress, it is crucial to consider gender-specific factors, as targeted approaches may be necessary to address the distinct challenges each gender faces.

The results of this study also indicate that the BOND Program may serve as a crucial tool in enhancing stress management and overall well-being among students by strengthening their social and coping abilities. In this regard, physical education is highlighted as an essential element of comprehensive development (Violant-Holz et al., 2020). As suggested by Yadav and Iqbal (2009), integrating programs that promote teamwork within physical education curricula can provide a valuable psychosocial intervention for addressing

bullying (Zych et al., 2015). This study emphasizes the importance of schools creating an environment that fosters reflection, resilience, and responsibility. Given the pivotal role education plays in shaping attitudes and behaviors, BOND Program presents an effective strategy for transforming educational practices and encouraging students to adopt positive behaviors as citizens. This approach should be aligned with the school's Safeguarding Children Policy to ensure that peer-on-peer abuse is treated as a serious threat to students' well-being.

However, despite the promising findings suggesting the BOND Program's potential in alleviating bullying-related stress, there are several limitations that must be acknowledged. A primary limitation is the relatively small sample size (N = 160), which stemmed from difficulties in recruiting schools and students to participate. Additionally, the participants were selected from specific regions and educational levels, which limits the representativeness of the sample and reduces the generalizability of the findings. Consequently, the conclusions drawn from this study are primarily applicable to the specific demographic group that was studied. Another limitation is the lack of long-term follow-up to examine the lasting effects of the BOND Program on stress. Future research should address this gap to gain a clearer understanding of the program's enduring impact. The study also faced challenges with missing data, and the analysis was based on the assumption that these missing data were random. Further sensitivity analyses would help determine if this assumption is valid and explore alternative methods for handling missing data. Finally, While this study provides valuable insights into the effectiveness of the BOND Program, it is important to acknowledge that school-specific factors may have influenced the outcomes of the intervention. For example, variations in school climate, including the level of support from school leadership, the availability of resources, and the general atmosphere regarding student well-being, could have played a significant role in determining the program's success. Additionally, the involvement of teachers, both in terms of their engagement with the program and their capacity to integrate its principles into daily practice, is a critical factor that could impact the effectiveness of the intervention. These variables should be considered in future studies, as they may contribute to differences in program outcomes across different school settings. Further research is needed to explore how school-specific factors interact with the intervention and whether adapting the program to particular school contexts can enhance its impact.

Despite these limitations, the findings provide valuable insights that can guide future research in this area. The significance of this research is underscored by the transformative potential of the BOND Program. As a straightforward yet effective intervention, it serves as a powerful tool for protecting student well-being and tackling the stressors associated with bullying. The promising outcomes from this study suggest that similar programs could play a vital role in fostering safer, more supportive educational environments.

5. Conclusions

As modern society becomes increasingly complex, there is a growing need for a redefined approach to education, one that not only prioritizes academic knowledge but also equips individuals with the skills necessary to navigate ever-evolving environments. In line with this goal, this study focused on developing, implementing, and evaluating a stress management and coping program based within physical education, specifically tailored for students who have experienced bullying. The key finding—that students who were victims of bullying showed a reduction in maladaptive coping strategies after the intervention—demonstrates the program's effectiveness. Moreover, the evidence that the BOND Program helps reduce stress, as reflected in improvements in heart rate variability

(HRV), further supports the positive outcomes of the intervention. These findings suggest that the program is particularly beneficial for students who are struggling with stress.

Given the promising outcomes of the BOND Program, its implementation in other educational settings holds considerable potential. The structure of the program—integrating stress management, embodied practices, and social–emotional learning within physical education—makes it adaptable to diverse school contexts, including primary and secondary education. To ensure successful adaptation, schools should consider aligning the program with their existing health and well-being curricula, while also providing training for educators to deliver the intervention effectively. Flexibility in scheduling and delivery formats (e.g., integrating it into PE classes, extracurricular activities, or wellness weeks) can further support implementation. Future pilot studies in varied educational environments would help assess the scalability and contextual responsiveness of the program, ensuring its relevance across different populations and institutional settings.

Despite these encouraging results, it is crucial for educational institutions to recognize the importance of such interventions, especially the BOND Program, as an essential strategy for improving student well-being and fostering positive social interactions. Schools should adopt this holistic approach as a part of their commitment to enhancing mental health and promoting healthier social dynamics within the school environment.

Looking ahead, future evaluations should assess bullying and victimization levels before and after the intervention, comparing experimental and control groups. It is essential that bullying and victimization are clearly defined and measured rigorously using quantitative methods. To strengthen the study design, random assignments should be applied to schools, classes, or individual students, depending on the nature of the intervention. For example, if the program includes training in interpersonal skills, randomization could assign students or classes to either the intervention or control group. Due to challenges in randomizing large numbers of schools, a more practical approach might involve pairing schools and assigning one to the experimental group and the other to the control group. Random assignment of classes alone may not suffice, as students in the control group could still be indirectly influenced by peers in the experimental group. To ensure the reliability of the analysis, only students who complete both pre- and post-intervention assessments should be included to reduce bias caused by uneven dropout rates.

To better understand the program's effectiveness, it will be important to examine the impact of individual components of the intervention. Randomly assigning students to receive or omit specific elements of the program could help determine which components are most beneficial. Additionally, further research is needed to establish optimal methods for measuring bullying, determining the best timeframes for assessments, and understanding how bullying behaviors may fluctuate seasonally.

While the present study provides strong evidence for the short-term effectiveness of the BOND Program, particularly in reducing maladaptive coping strategies and improving physiological indicators of stress such as heart rate variability (HRV), the question of long-term impact remains open. To fully understand the sustained benefits of the intervention, future research should incorporate follow-up assessments several months after the conclusion of the program. This would allow for the evaluation of whether improvements in stress regulation and coping strategies are maintained over time, and whether they translate into long-term changes in students' social functioning and psychological well-being. Monitoring long-term outcomes is particularly relevant for educational institutions aiming to adopt evidence-based programs that not only address immediate needs but also foster lasting resilience and positive behavioral change.

Finally, it is crucial to establish clear methodological standards for evaluating interventions aimed at reducing bullying. These standards could serve as a guide for researchers,

policymakers, and educational institutions in assessing the credibility and validity of intervention outcomes. Such guidelines should specify the key elements that should be included in published evaluations, ensuring that the findings are reliable and can inform future program development. Adhering to these standards will help create a stronger evidence base for effective bullying prevention and stress management strategies in educational settings.

Author Contributions: Conceptualization, F.L.; methodology, F.L.; software, F.L. and F.T.; validation, F.L.; formal analysis, F.L.; investigation, F.T.; resources, D.T.; data curation, F.L. and F.T.; Bibliographical research, F.T.; writing—original draft preparation, F.L.; writing—review and editing, F.L.; supervision, D.T.; funding acquisition, D.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by Department of Medical Science, Exercise, and Wellbeing at the University of Naples "Parthenope" (DiSMMeB Prot. N. 88592/2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

Conflicts of Interest: The authors declare no conflicts of interest.

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