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Review

# Exploring the Potential of Biofeedback in Promoting Student Well-being: A SWOT Analysis

José Maria Fialho <sup>1,2,\*</sup>, Patrícia Batista <sup>3</sup>, Osvaldo Santos <sup>2,4</sup>, Miguel Arriaga <sup>4,5,6</sup> and Anabela Pereira <sup>1</sup>

<sup>1</sup> Department of Psychology, Center for Research in Education and Psychology (CIEP), University of Évora, Évora, Portugal

<sup>2</sup> Environmental Health Behaviour Lab, Faculty of Medicine, University of Lisbon, Lisbon, Portugal

<sup>3</sup> Human Neurobehavioral Laboratory, Faculty of Education and Psychology, Catholic University of Portugal, Porto, Portugal

<sup>4</sup> Institute of Environmental Health, Faculty of Medicine, University of Lisbon, Lisbon, Portugal

<sup>5</sup> Direção- Geral da Saúde, Portugal

<sup>6</sup> RC-W - Católica Research Center for Psychological, Family and Social Wellbeing, Universidade Católica Portuguesa, Lisbon, Portugal

\* Correspondence: [jmfvb.fialho@gmail.com](mailto:jmfvb.fialho@gmail.com); Tel.: +351 911732105

## Abstract

Anxiety is prevalent among college students and can be detrimental to well-being, academic success, and mental health. Alternative treatments have been suggested, among which biofeedback stands out as a non-pharmacological and individualized intervention. This article aims to examine the role of biofeedback in reducing anxiety among college students. For that, we carried out an initial literature review, mainly based on a recent systematic review, to conduct a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. Evidence indicates that biofeedback lowers anxiety and is well accepted by students. Limitations concern methodological issues of the studies on this intervention (e.g., small sample sizes, no active control groups, and limited long-term follow-up). The rise of mobile and biometric technologies provides opportunities for interventions to become more accessible. However, obstacles such as the stigmatization of seeking psychosocial care, low adherence to preventive measures, and logistical barriers persist. Biofeedback has proven to be a safe and effective treatment modality, nevertheless, further efforts are needed to support its integration and applicability within academic environments.

**Keywords:** university students; biofeedback; well-being; self-regulation techniques; stress management

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## 1. Introduction

University students constitute a population that has been consistently identified as particularly vulnerable to mental health problems. Epidemiological evidence indicates that symptoms of anxiety, depression, and stress are highly prevalent in this group, with large international surveys suggesting that roughly one third of first-year students meet criteria for at least one common mental disorder during the past 12 months (Auerbach et al., 2018).

Entering higher education often coincides with a period marked by substantial academic, social, and personal changes. The need to adapt to new learning demands, increased autonomy, financial pressures, and uncertainty regarding future career prospects may place students at heightened psychological risk. In this context, anxiety has emerged as one of the most frequently reported mental health concerns in university populations, which has contributed to the growing research attention devoted to this topic in recent years (Caldarelli et al., 2024).

Parallel to this increase in scientific interest, higher education institutions have shown greater awareness of students' mental health needs. Academic stress, performance-related anxiety, and depressive symptoms are repeatedly described as central challenges during the university experience. These difficulties are commonly associated with heavy academic workloads, financial strain, and high self-imposed expectations, and have been linked to poorer psychological well-being and reduced academic functioning and academic-related performance (Caldarelli et al., 2024; Ravada et al., 2023; Rosenberg & Hamiel, 2021).

Although evidence-based psychological interventions, such as psychotherapy, including cognitive-behavioral approaches, are available and have demonstrated effectiveness in reducing anxiety and psychological distress, a considerable number of students do not seek professional support. Research suggests that this reluctance is often related to perceived stigma, limited time availability, and a preference for managing difficulties independently, rather than to a lack of perceived need (Lin et al., 2021; Ponzo et al., 2020). As a result, universities face an increasing demand for intervention models that are accessible, acceptable to students, and capable of complementing existing mental health services.

High levels of stress and anxiety have been shown to affect students beyond their emotional well-being. Difficulties with concentration, increased depressive symptoms, and reduced academic engagement have all been associated with sustained exposure to academic stressors (Ravada et al., 2023). Consequently, the development and implementation of strategies that support effective stress and anxiety regulation have been widely recognized as an important component of student well-being initiatives in higher education (Fialho & Pereira, 2023).

Within this framework, biofeedback has gained attention as a non-pharmacological intervention grounded in psychophysiological self-regulation. Biofeedback systems provide individuals with real-time information about physiological processes, such as heart rate variability, respiration, muscle tension, or skin conductance, allowing them to become more aware of their stress responses and to learn how to modulate them voluntarily (Fialho & Pereira, 2023; Wang et al., 2022). By fostering greater awareness of autonomic activation and promoting adaptive regulation, biofeedback aims to reduce maladaptive physiological patterns commonly associated with anxiety.

Over the past decades, the application of biofeedback has extended beyond traditional clinical settings and has increasingly been explored in educational and non-clinical contexts. Studies conducted with university students suggest that biofeedback-based interventions may contribute to reductions in anxiety and stress levels, alongside improvements in perceived well-being (Ponzo et al., 2020; Ravada et al., 2023). Randomized controlled trials have reported significant decreases in perceived stress and anxiety following structured biofeedback training, with some studies also documenting changes in psychophysiological indicators and depressive symptoms (Ponzo et al., 2020; Wang et al., 2022).

Despite these encouraging findings, the existing literature also points to several limitations that warrant careful consideration. Not all studies report consistent effects, and practical challenges related to intervention feasibility, student adherence, and integration within institutional contexts remain evident (Lin et al., 2021). Moreover, authors have emphasized the importance of adapting biofeedback interventions to specific educational and institutional contexts to maximize their relevance and effectiveness (Apostolidis & Tsiatsos, 2021; Pereira & Chaló, 2023).

Taken together, these considerations highlight the need for a balanced and systematic examination of biofeedback interventions in higher education. In this context, the present article adopts a SWOT framework to explore the strengths, weaknesses, opportunities, and threats associated with the use of biofeedback for promoting psychological well-being among university students. By drawing on recent empirical evidence, this analysis aims to inform evidence-based decision-making regarding the integration of biofeedback into psychological and psychoeducational support services within higher education institutions.

## 2. Materials and Methods

This article adopts a SWOT analytical framework to critically examine the feasibility and effectiveness of biofeedback as an anxiety reduction intervention in higher education. A customized search strategy was implemented in EBSCOhost, PubMed, and Scopus, using descriptors related to anxiety and stress (e.g., “anxiety”, “stress”), biofeedback, and higher education student populations (e.g., “university students”, “college students”, “higher education”), with minor database-specific adjustments to maximize retrieval; searches were limited to the title, abstract, or keywords fields. Only full-text, peer-reviewed journal articles published between 2018 and 2025 were included, and manual screening of reference lists identified additional eligible studies. Based on the summative results of the review, a SWOT analysis was conducted to integrate internal evidence (i.e., intervention effectiveness, feasibility, and student acceptability) with external considerations (e.g., institutional barriers, implementation challenges, and future scale-up possibilities), providing a strategic overview of biofeedback’s positioning within a university’s broader mental health promotion efforts.

## 3. Analysis and Discussion of Results

### 3.1. Strengths

The available evidence highlights multiple strengths that position biofeedback as a credible and scalable option for anxiety reduction in higher education. First, effectiveness is supported across controlled trials in student samples. Ravada et al. (2023), in first-year medical students, reported meaningful reductions in anxiety and stress following a structured biofeedback program, with improvements that were significantly greater than those observed in the comparison condition. In Portugal, Chaló et al. (2017) showed that a brief protocol delivered in eight weekly sessions was sufficient to reduce anxiety and stress in anxious freshmen compared with a control group; notably, this intervention used skin conductance biofeedback combined with guided breathing and required minimal session time, reinforcing its practical fit for academic settings despite some attrition.

Beyond individual trials, the broader evidence base is consistent. Henriques et al. (2011) found that biofeedback-based training was associated with reductions in anxiety-related outcomes in university students. At the synthesis level, Goessl, Curtiss, and Hofmann (2017) reported, in a quantitative meta-analysis, large reductions in self-reported stress and anxiety both within groups (pre–post) and relative to control conditions, suggesting a robust overall effect. Similarly, the systematic review by Fialho and Pereira (2023), covering studies published between 2018 and 2023, concluded that biofeedback interventions in university populations were generally associated with reductions in anxiety and stress indicators and were viewed as promising additions to campus mental health provision.

A second strength is that benefits can extend beyond subjective reports to measurable psychophysiological markers, particularly in approaches explicitly targeting autonomic regulation. In a brief, single-session HRV biofeedback protocol, Demin and Poskotinova (2025) observed acute neurophysiological and autonomic changes consistent with downregulated arousal, including increased alpha-band activity on EEG alongside changes in HRV-related indices (e.g., increases in SDNN/total power and reductions in stress-index parameters). Collectively, these findings reinforce that biofeedback can operate as both a psychological and physiological regulation strategy, rather than a purely perceptual calming technique.

Third, biofeedback may deliver multidimensional mental health gains, which is strategically valuable for universities aiming to address comorbidity and functional impairment through integrated support options. Ratanasiripong et al. (2015) reported that a brief biofeedback intervention significantly reduced state anxiety in nursing students and maintained perceived stress levels during the transition into clinical training. Ponzio et al. (2020) found that a digital, smartphone-based biofeedback intervention reduced anxiety and improved psychological well-being in university students, with additional improvements observed in depressive symptomatology and effects

sustained at follow-up. This pattern suggests that biofeedback can contribute to broader well-being benefits, aligning with stepped-care models that prioritize scalable, low-threshold supports.

Finally, biofeedback has operational advantages that support institutional uptake. As a non-pharmacological, training-oriented approach, it is compatible with preventive and psychoeducational service models and can be embedded into routine student support pathways (Neto, 2010). Its emphasis on skill acquisition (e.g., breathing-based self-regulation supported by feedback) enables transfer to day-to-day academic stressors and may reduce reliance on continuous professional input once competencies are established (Neto, 2010). Looking ahead, technology-focused work on endogenous-rhythm-based systems and neurobiocontrol solutions (e.g., EEG, heart rate, respiration) may inform future delivery formats for biofeedback interventions, particularly where digital delivery and wearable integration are strategic priorities (Fedotchev, Parin, & Polevaya, 2022). Taken together, the evidence supports biofeedback as an effective, mechanism-consistent, and institutionally compatible option for higher education mental health initiatives.

### 3.2. Weaknesses

Despite promising outcomes, the current evidence base has limitations that temper confidence in biofeedback's effectiveness and scalability in higher education and point to clear priorities for methodological improvement. A first constraint is that several student-focused trials rely on small, convenience-based, and context-specific samples, which reduces statistical power and weakens generalizability; for example, the Portuguese freshman trial included 25 participants in the biofeedback group and 19 in the control group and explicitly notes both a small sample and gender imbalance, as well as the fact that the study was conducted in a single Portuguese university, requiring caution when extrapolating to other settings (Chaló et al., 2017). Similar concerns emerge in other campus studies, including uneven gender distributions (e.g., 82% women in one reviewed trial), strict eligibility criteria, and limited assessment of mediators, all of which constrain external validity and hinder decision-making for institution-wide adoption (Fialho & Pereira, 2023). In addition, some studies acknowledge self-selection as a limitation and emphasize the need to recruit more male participants and broader student groups to strengthen representativeness (Ravada et al., 2023).

A second weakness concerns risk of bias in study designs, particularly the frequent use of passive or waitlist controls and limited blinding procedures. Ravada et al. (2023) used a pretest–posttest control group design in which the control group received no treatment, making it difficult to separate biofeedback-specific effects from non-specific influences such as attention, expectancy, or study participation (Ravada et al., 2023). Ponzio et al. (2020) similarly employed a randomized waitlist-controlled design and, although initially planned as single-blind, reported that the study was ultimately unblinded for logistical reasons—an issue that can inflate observed effects in self-report outcomes (Ponzio et al., 2020). Moreover, even when both groups improve over time, the absence of a waitlist or meditation-only arm can limit causal attribution and mechanism clarification when estimating the incremental contribution of a biofeedback device (Lin et al., 2021). These patterns reinforce the strategic need for stronger comparators (e.g., active controls, attention-matched interventions, or sham biofeedback) to isolate biofeedback's incremental value.

A third limitation is intervention complexity and component confounding. Many biofeedback programs embed additional elements—paced breathing, relaxation instructions, psychoeducation, and in-app behavioral recommendations—making it difficult to determine which components drive benefits and whether biofeedback adds meaningful value beyond low-cost, equipment-free alternatives. In the BioBase trial, the intervention included multiple in-app tools and techniques (including breathing and relaxation strategies), and the review evidence explicitly notes that it was not possible to differentiate the effects of distinct program components (Ponzio et al., 2020; Fialho & Pereira, 2023). Evidence from acute comparisons also illustrates that brief interventions can produce emotional benefits through multiple routes, underscoring why direct, component-sensitive

comparisons are important when positioning biofeedback against other scalable options (Meier & Welch, 2015).

A fourth weakness is the limited and inconsistent use of longer-term follow-up and objective outcome reporting. Several trials assess outcomes only immediately post-intervention; in the Portuguese freshman study, authors explicitly note the absence of follow-up assessments, limiting conclusions about durability of effects, and report that physiological data export/analysis was not feasible due to a missing statistical module, leading outcomes to rely on self-report inventories (Chaló et al., 2017). While newer work is beginning to address the objective-measurement gap—e.g., Wang et al. (2022) incorporated physiological indices and pioneered speech-feature and deep-learning approaches as objective markers and predictors of response—this remains the exception rather than the norm, and the authors themselves acknowledge the need for replication and stronger evidence linking certain objective indicators to clinical change (Wang et al., 2022). Importantly, critical synthesis also warns that clinical improvements do not always align neatly with physiological measures, highlighting a persistent mechanism and measurement challenge in the biofeedback literature (Lantyer et al., 2013).

Finally, implementation and ecological validity constraints remain salient for higher education scale-up. Key barriers include device adoption and adherence burden, dependence on vendor collaboration and data accessibility, and uncertainty about whether outcomes achieved under study conditions will generalize to routine, campus-wide delivery models (Lin et al., 2021; Fialho & Pereira, 2023). Taken together, these limitations—sample and setting constraints, suboptimal control/blinding, multicomponent confounding, short follow-up windows, and inconsistent physiological reporting—suggest that the field is ready for more rigorous, implementation-aware trials designed to quantify biofeedback's incremental value over scalable comparators in authentic university contexts.

### 3.3. Opportunities

The environmental scan identifies several external trends that may enhance the future effectiveness and scalability of biofeedback interventions for anxiety management in university populations. A central opportunity is the pace of technological evolution in digital and mobile health. The growing availability of wearable devices and mobile platforms is enabling biofeedback-informed self-regulation to move beyond clinical or laboratory settings and be practiced in real-life contexts through continuously monitored physiological signals and timely, in-the-moment prompts and feedback (Lin et al., 2021).

The study by Ponzo and colleagues (2020) illustrates this potential in a student population by testing the BioBase program, which combines a mobile app with a wearable sensor (BioBeam). The intervention integrates psychoeducational content, mood tracking (EMA), and in-the-moment tools (e.g., diaphragmatic breathing and relaxation techniques), while the wearable collects passive physiological and behavioral data (e.g., sleep, heart rate, and physical activity) that are displayed to users through an in-app dashboard (Ponzo et al., 2020). The findings showed that a four-week intervention reduced anxiety and improved well-being, with effects sustained two weeks after the end of the intervention (Ponzo et al., 2020). This format is strategically attractive for universities because it is scalable, time-flexible, and compatible with low-threshold access models, thereby extending support beyond the constraints of one-to-one services (Ponzo et al., 2020).

These findings suggest that digital biofeedback-enabled tools could be integrated into university mental health strategies as complementary resources within stepped-care or hybrid care pathways. For example, students in psychotherapy could use app-based self-regulation tools to reinforce skills between sessions, and students on waiting lists could use them to mitigate symptom escalation, while continuing to rely on professional care when clinically indicated.

Another promising opportunity lies in advances in objective markers and personalization. Wang et al. (2022) incorporated speech acoustic features and physiological signals to track change and predict response to biofeedback in college-going students, reporting improvements in anxiety, stress,

and insomnia and identifying speech features (energy parameters and MFCC) as candidate objective indicators. Using an artificial neural network model, classification accuracy for response versus non-response was approximately 60%, suggesting early potential for data-informed stratification and optimization of delivery (Wang et al., 2022). Over time, such approaches could support adaptive protocols that adjust training emphasis based on users' engagement patterns and objective response signals, while also enabling remote monitoring of risk trajectories.

At the institutional level, the wider student well-being literature supports the feasibility of embedding structured stress-management, relaxation, and psychoeducational initiatives within curricula and campus systems, alongside screening and accessible support pathways, rather than relying on a single intervention modality (Frajerman, 2019). Within this broader prevention architecture, biofeedback could be positioned as a skills-based, measurable self-regulation component delivered via workshops, guided practice, or digital formats, particularly during high-demand academic periods.

Opportunities also exist to tailor biofeedback to discrete student subpopulations and contexts. Demin and Poskotinova (2025) highlight the relevance of HRV biofeedback for psychophysiological adaptation in international students studying in harsh environments (e.g., the Arctic), showing acute changes consistent with downregulated arousal (e.g., increased HRV indices and increased EEG alpha activity during training). This supports targeted applications in niches such as international student transition programs or high-pressure academic tracks, where rapid self-regulation capacity may be especially valuable (Demin & Poskotinova, 2025).

Taken together, the technological, institutional, and scientific landscape indicates an opportune moment to scale biofeedback-enabled self-regulation in higher education, provided implementation pathways prioritize evidence-based integration, appropriate governance, and rigorous evaluation of added value over scalable comparators.

### 3.4. Threats

Despite the growing evidence base supporting biofeedback for anxiety- and stress-related outcomes in student samples, several external threats may hinder implementation, uptake, and long-term sustainability in higher education.

A primary threat is limited engagement with psychological support resources among students, even when services exist. Cross-national evidence from first-year college students indicates that only a minority report they would "definitely" seek professional help in the event of an emotional problem, and that attitudinal barriers dominate over structural ones. The most endorsed reasons for not seeking treatment include a preference to handle the problem alone, wanting to talk to friends or relatives instead, and embarrassment, with time/scheduling also present as a barrier for a substantial subgroup (Ebert et al., 2019). A broader synthesis focused on adolescents and young adults similarly identifies stigma/embarrassment and self-reliance as prominent barriers to help-seeking (Gulliver et al., 2010). These same barriers can reasonably be expected to reduce initiation and completion of biofeedback training, particularly when sustained participation is required.

A second threat concerns adherence and the "dose" needed to achieve benefits. Several biofeedback protocols require repeated sessions over weeks; for example, Ravada et al. (2023) delivered a 10-session program over approximately 10–12 weeks, and effects were observed under controlled study conditions with a no-treatment control group (Ravada et al., 2023). Similarly, digital delivery may reduce access barriers, but effectiveness remains contingent on continuous user engagement with program components. In the BioBase trial, the intervention was multidimensional (psychoeducation, EMA mood tracking, in-the-moment exercises such as breathing/relaxation) supported by passive wearable data displayed in-app (Ponzo et al., 2020). Without sustained engagement, real-world effectiveness may fall below efficacy observed in trials.

A third threat is heterogeneity in psychophysiological response and the risk that "one-size-fits-all" protocols underperform across diverse student groups. Demin and Poskotinova (2025) demonstrate differential baseline autonomic profiles and distinct EEG/HRV response patterns during

short-term HRV biofeedback in Indian versus Russian students studying in the Arctic, suggesting that contextual and individual factors can shape physiological responsivity (Demin & Poskotinova, 2025). Such heterogeneity raises implementation risk if programs are deployed without adaptive pathways, appropriate screening, or protocol tailoring.

A fourth threat relates to the credibility and safety profile of biofeedback in institutional environments when consumer-grade devices or poorly validated implementations are adopted. Independent feasibility work cautions against the uncritical use of commercially produced wearable biofeedback devices without appropriate regulatory approval for clinical monitoring and highlights practical barriers (e.g., adherence uncertainties, device validity questions, and challenges in transparency and data sharing with vendors), all of which can undermine institutional trust and continuity of provision (Lin et al., 2021). In this context, suboptimal outcomes may be misattributed to biofeedback as an approach rather than to implementation quality, reducing stakeholder buy-in and threatening sustainability.

Taken together, the main threats are (i) persistent attitudinal barriers that limit uptake, (ii) engagement and adherence risks that can dilute real-world impact, (iii) variability in response across student subgroups, and (iv) reputational and governance risks linked to device validity, oversight, and vendor dependence. Addressing these threats requires implementation plans that prioritize low-stigma access routes, engagement design, protocol flexibility, and robust quality assurance aligned with evidence-based standards (Ebert et al., 2019; Gulliver et al., 2010; Lin et al., 2021).

**Table 1.** SWOT analysis of biofeedback for anxiety reduction among university students.

S	W	O	T
Efficacy in reducing anxiety and stress. Associated physiological and neurophysiological changes. Absence of adverse effects. Promotion of self-regulation. Strong user engagement.	Small sample sizes and limited generalizability. Methodological limitations (lack of active controls and blinding). Short-term follow-ups and scarce longitudinal data. Dependence on self-report measures. Limited standardization of biofeedback protocols.	Integration of digital and mobile technologies (AI, apps, wearables). Interdisciplinary collaborations (psychology, data science, engineering). Institutional implementation in student health programs. Use in preventive interventions and early stress detection. Increasing recognition of student mental health needs.	Low adherence or engagement from highly anxious students. Financial and logistical barriers in universities. Cultural variability and differences in responsiveness. Risk of unvalidated or poorly implemented programs. Perception of biofeedback as “experimental” or low priority.

#### 4. Conclusions

This study offered a comprehensive and integrated analysis of the effectiveness of biofeedback in reducing anxiety among college students according to the SWOT matrix quadrants. Although the full picture is not yet complete, the cumulative evidence suggests a positive verdict: biofeedback

appears to be an efficacious, safe, and well-tolerated intervention that can significantly reduce moderate to high levels of stress and anxiety common in academic settings.

RCTs indicate that relatively brief biofeedback programs can effectively reduce self-reported anxiety while increasing physiological indicators of autonomic balance, possibly resulting in improved well-being and performance. The advantages of biofeedback alone, along with its non-drug and non-invasive nature and the empowerment it gives individuals, make it increasingly valuable at a stage of life when young adults are under significant pressure to adapt to multiple challenges. We believe that, at this moment, biofeedback should be considered a promising and ecologically valid tool to alleviate anxiety and stress in the university setting.

The SWOT analysis revealed that the strengths and opportunities of biofeedback, such as its scientific evidence and breadth of digital applications, outweigh its weaknesses and threats when accompanied by appropriate response-taking activities. From a practical standpoint, this review highlights the importance of several key lines of action: (1) testing biofeedback programs on campus in a controlled way, through short training sessions with student groups presenting high baseline anxiety and rigorous evaluation of outcomes to manage expectations; (2) training professionals (psychologists, therapists, or qualified monitors) to conduct biofeedback sessions and analyze data, ensuring protocol consistency and quality; (3) testing digital biofeedback platforms to complement in-person sessions, potentially filling an access gap for students who may prefer lower-cost, self-led interventions; and (4) pursuing continued research through multicenter and interdisciplinary studies that move beyond proof-of-concept approaches to explore mechanisms of action, duration of effects, and potential moderating factors of biofeedback effectiveness.

Ultimately, in a climate where attending to student mental health is increasingly recognized as essential for both academic and personal flourishing, the role of biofeedback should not be viewed as a distinctive alternative or a “magic bullet,” but rather as one tool among many that can be integrated into broader intervention strategies. Biofeedback empowers students with practical anxiety self-regulation skills—skills that have implications for all aspects of their lives: academically, during their studies, and post-academia, when facing personal or work-related stress.

Institutions and mental health professionals are therefore urged to consider the informed use of biofeedback, guided by synthesized evidence, as a proactive step toward creating healthier, more resilient, and student-centered educational environments.

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## Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
BFB	Biofeedback

HRV	Heart Rate Variability
RCTs	Randomized Controlled Trials
SWOT	Strengths, Weaknesses, Opportunities, and Threats

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