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REVIEW ARTICLE

From salutogenic resources to objective stress phenotyping in university students: a critical narrative review of sense of coherence, lifestyle, and physiological measurement

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ABSTRACT

Objective: To critically examine how sense of coherence (SOC), lifestyle, and objective physiological stress measurement can be integrated in university-student research without overstating the maturity of the evidence.

Methods of synthesis: This problem-oriented critical narrative review was anchored in a prior integrative review on SOC and lifestyle in university students and expanded through targeted searches in PubMed/MEDLINE, Scopus, Web of Science, IEEE Xplore, ACM Digital Library, and Google Scholar, supplemented by reference tracking. The search strategy combined controlled vocabulary where available and free-text descriptors related to four blocks: student populations; salutogenesis and lifestyle; academic stress and mental health; and physiological or digital stress measurement, including wearables, HRV, sleep, passive sensing, salivary biomarkers, stress detection, machine learning, and sensor-supported interventions. Literature from 2015 to 2025 was prioritized, while foundational salutogenesis sources were retained for conceptual grounding. Studies were selected when they clarified the target population, stress label, physiological endpoint, device or biomarker protocol, analytical strategy, or implementation constraint relevant to multimodal stress phenotyping.

Main findings: Direct evidence in university students supports associations among stronger SOC, more favorable lifestyle profiles, and lower psychological distress. Parallel evidence shows that sleep, cardiorespiratory signals, passive sensing, salivary cortisol, and total antioxidant capacity may characterize aspects of stress physiology, but their interpretability depends on temporal alignment, stress-label validity, device and pipeline transparency, pre-analytical control, and participant adherence. The link between SOC and physiological endpoints is therefore best treated as an integrative inference requiring direct validation.

Conclusion: The most defensible contribution of the field is not the demonstration of a validated causal chain from SOC to biomarkers, but the formulation of auditable methodological conditions for future multimodal studies that analyze psychosocial resources, behavioral exposures, and physiological endpoints within the same observation window.

KEYWORDS
sense of coherence; salutogenesis; academic stress; physiological monitoring; salivary biomarkers; wearable devices.

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Introduction

University life is a transition period in which academic overload, sleep restriction, social reorganization, financial insecurity, and increased self-management may converge to intensify psychological distress and health-related behavioral disorganization. In this population, prior synthesis and empirical studies have associated stronger sense of coherence (SOC) and more favorable lifestyle patterns with better well-being and lower levels of stress, anxiety, or depression.[1–4] Within the salutogenic model, SOC is not a biological endpoint. It is a psychosocial orientation through which demands are perceived as comprehensible, manageable, and meaningful. Its value is therefore explanatory and contextual: it helps interpret why some students may organize protective routines and cope more adaptively under persistent academic demands, while others may become more vulnerable to behavioral disorganization and distress.[5–7]

In parallel, student-health research has increasingly adopted objective or semi-objective approaches to physiological stress measurement, including wearable-derived sleep and cardiorespiratory metrics, passive sensing, electrodermal activity, salivary cortisol, total antioxidant capacity, and predictive modeling. These studies demonstrate feasibility and methodological promise, but they also reveal substantial heterogeneity in stress labels, devices, sampling windows, preprocessing pipelines, biological collection routines, and validation strategies.[8–17]

The central problem is that these two lines of literature have advanced largely in parallel. The SOC and lifestyle literature provides direct student-centered evidence but remains predominantly psychometric and self-reported. The wearable, biomarker, and modeling literature provides physiological resolution but rarely measures salutogenic resources and lifestyle exposures in the same temporally aligned design. As a result, claims linking SOC, lifestyle, and physiological stress markers should be treated as plausible, behavior-mediated, and method-dependent rather than as an already validated direct pathway. Accordingly, the novelty of this review lies in organizing these domains under an explicit evidentiary hierarchy. Instead of presenting multimodal stress phenotyping as an automatic technological advance, the review distinguishes what is directly supported in university students, what is supported by parallel physiological-monitoring research, and what remains an integrative inference requiring future validation.

Review objective

This critical narrative review examines how SOC, lifestyle, and objective physiological stress measurement can be articulated in university-student research under explicit criteria of validity, reproducibility, and translational interpretability. The specific aim is to define the methodological conditions under which multimodal stress phenotyping may become scientifically testable rather than merely conceptually attractive.

Review method and interpretive strategy

Design and scope

This study is a problem-oriented critical narrative review, deliberately interpretive rather than exhaustive, designed to examine how sense of coherence (SOC), lifestyle, and objective physiological stress measurement can be conceptually and methodologically integrated in university-student populations. Rather than estimating pooled effects or mapping all available studies, the review provides a transparent critical synthesis capable of distinguishing what is directly supported in university-student research, what is supported by parallel physiological-measurement literature, and what remains an integrative inference requiring future validation.

Information sources and search strategy

The synthesis was anchored in a prior integrative review on SOC and lifestyle in university students and expanded through a targeted literature search focused on wearable technologies, passive sensing, salivary biomarkers, predictive modeling, and sensor-supported interventions. The literature search was conducted in PubMed/MEDLINE, Scopus, and Web of Science. Because part of the physiological-monitoring and stress-detection literature is published in engineering and digital-health venues, complementary searches were also performed in IEEE Xplore, ACM Digital Library, and Google Scholar. Reference tracking of key publications was used to identify additional studies relevant to the conceptual or methodological aims of the review. The principal empirical and review search window was January 2015 to December 2025, chosen to capture contemporary developments in wearable-based physiological monitoring, passive sensing, biomarker research, and machine-learning approaches to stress detection. Seminal sources on salutogenesis and SOC were retained outside this interval when necessary for conceptual grounding.

Descriptors and search combinations

Search expressions combined controlled vocabulary when available and free-text terms adapted to the scope of each database. The search strategy was organized into four conceptual blocks: population terms ('university students', 'college students', 'medical students', 'dental students'); salutogenic and lifestyle terms ('sense of coherence', 'SOC', 'salutogenesis', 'lifestyle', 'health behavior', 'health-related behavior'); stress and mental-health terms ('academic stress', 'student stress', 'perceived stress', 'psychological distress', 'anxiety', 'depression'); and physiological or digital measurement terms ('wearable devices', 'smartwatch', 'physiological monitoring', 'heart rate variability', 'HRV', 'sleep', 'respiratory rate', 'passive sensing', 'salivary cortisol', 'salivary biomarkers', 'total antioxidant capacity', 'stress detection', 'machine learning', 'sensor-supported intervention').

Representative Boolean combinations included: ('sense of coherence' OR SOC OR salutogenesis) AND ('university students' OR 'college students' OR 'medical students' OR 'dental students') AND (lifestyle OR 'health behavior' OR 'psychological distress'); ('academic stress' OR 'student stress' OR 'perceived stress') AND ('wearable devices' OR smartwatch OR 'physiological monitoring' OR HRV OR sleep); ('student stress' OR 'academic stress') AND ('salivary cortisol' OR 'salivary biomarkers' OR 'total antioxidant capacity'); ('stress detection' OR 'stress prediction') AND ('wearable sensors' OR smartwatch OR 'passive sensing') AND ('machine learning' OR model OR classification); and ('sensor-supported intervention' OR 'in-the-moment intervention') AND (stress OR anxiety) AND (wearable OR sensor). These combinations were adapted to the syntax and indexing structure of each database.

Eligibility and selection criteria

Studies were considered eligible when they contributed relevant empirical evidence, conceptual grounding, or methodological insight to at least one of the following domains: (i) SOC, salutogenesis, lifestyle, academic environment, psychological distress, or mental health in university, college, medical, or dental students; (ii) physiological stress measurement using wearable or sensor-based devices; (iii) salivary biomarkers of stress, particularly cortisol and related physiological markers; (iv) stress detection, stress-label definition, predictive modeling, passive sensing, or machine-learning approaches; and (v) sensor-supported monitoring or intervention strategies relevant to stress, anxiety, or real-world implementation.

Empirical studies, systematic reviews, scoping reviews, integrative reviews, and methodologically informative digital-health or sensor-modeling studies were considered. Conference papers were retained only when they provided a clear methodological contribution to passive sensing, ecological validity, stress-label definition, or signal interpretation. Priority was given to peer-reviewed publications and to studies with sufficient methodological detail to support critical appraisal.

Studies were excluded or not prioritized when they were only indirectly related to student populations or stress measurement, lacked sufficient methodological description, focused exclusively on psychological stress without relevance to physiological or behavioral measurement, reported device-generated proprietary composite scores without adequate explanation of the underlying variables, or did not contribute meaningfully to the review's conceptual framework or methodological agenda.

Definition of methodologically representative studies

For the purposes of this review, 'methodologically representative studies' were defined as studies that did not necessarily cover the entire field exhaustively, but that illustrated key methodological problems or advances relevant to multimodal stress phenotyping. These included studies showing how stress can be measured through wearable-derived sleep or cardiorespiratory variables, how salivary biomarkers depend on pre-analytical control, how predictive models are influenced by stress-label definition, and how sensor-supported approaches may be limited by adherence, usability, ecological validity, and participant burden.

Study selection and critical appraisal

Study selection followed an interpretive and purposive rationale rather than a predefined exhaustive screening protocol. First, titles, abstracts, and keywords were screened for relevance to the review objective and to the search blocks. Second, full texts or complete methodological descriptions were examined to determine whether each study could support critical discussion of design, population characteristics, measurement protocol, physiological endpoint, biological sampling procedure, analytical strategy, stress-label definition, or implementation constraint.

No formal risk-of-bias scoring, quantitative synthesis, or PRISMA flow diagram was applied because the manuscript is not a systematic review. Consequently, the findings should be interpreted as a structured critical synthesis rather than as an exhaustive evidence map. Critical appraisal focused on whether each study could support one of the manuscript's analytical purposes: defining the direct student-centered evidence base; identifying parallel evidence from physiological and digital stress-monitoring literature; or clarifying methodological requirements for future multimodal studies.

Analytical organization and evidence tiers

The synthesis was organized into five analytical domains: (i) SOC as a salutogenic resource; (ii) lifestyle as a behavioral and temporal interface between academic context and physiological load; (iii) wearable devices and transparent physiological endpoints; (iv) salivary biomarkers and pre-analytical control; and (v) challenges related to stress labeling, predictive modeling, implementation, and participant adherence.

Throughout the review, claims were classified into three levels of evidence: direct evidence, parallel evidence, and integrative inference. Direct evidence refers to studies conducted in university-student populations linking SOC, lifestyle, academic environment, psychological distress, or mental-health outcomes. Parallel evidence refers to studies showing the feasibility, promise, or limitations of physiological stress measurement through wearables, salivary biomarkers, passive sensing, or predictive modeling, even when SOC was not directly measured. Integrative inference refers to the interpretive synthesis proposing how salutogenic resources, behavioral exposures, and physiological endpoints may be combined in future multimodal research without assuming a validated causal pathway.

Accordingly, this review does not claim causal demonstration. Its purpose is to provide a transparent, critically structured, and translationally interpretable synthesis of the methodological conditions required for future studies that aim to integrate SOC, lifestyle, and objective physiological stress phenotyping in university students.

Thematic synthesis of the literature

Direct evidence: SOC, lifestyle, and psychological distress in university students

The most direct evidence available for the target population concerns associations among SOC, lifestyle, academic environment, and mental health. The prior integrative synthesis on SOC and lifestyle indicates that students with stronger SOC tend to report healthier lifestyle profiles and better psychosocial adjustment.[1] The German COVID-HL survey similarly linked SOC dimensions with well-being and fewer health complaints during a period of intensified uncertainty.[2] Brazilian student studies further support the relevance of lifestyle and academic environment to mental health, including associations between SOC, perceived academic context, social support, and symptoms of depression, anxiety, and stress.[3,4]

The contribution of this evidence is important but bounded. It justifies treating SOC as a salutogenic resource relevant to student vulnerability and resilience, but it does not, by itself, demonstrate a physiological mechanism. Most of this literature relies on cross-sectional designs, self-reported exposures, and questionnaire-based outcomes. Consequently, the defensible claim is not that SOC directly regulates biomarkers, but that SOC may help explain behavioral organization, coping quality, and perceived stress in ways that could influence physiological burden over time.

This distinction strengthens the manuscript's central framework. SOC should be positioned as a psychosocial explanatory layer, lifestyle as the behavioral and temporal interface, and physiological measurement as an additional layer of resolution. Only when these layers are measured in the same observational window can the proposed bridge move from inference to direct evidence.

Lifestyle as the behavioral and temporal interface

Lifestyle is the most plausible operational bridge between salutogenic resources and physiological load.

Sleep timing and duration, physical activity, sedentary behavior, dietary regularity, substance use, and daily routine stability are behavioral exposures that can be aligned with academic stressors and physiological outcomes. In this sense, lifestyle should not be treated as a generic background variable. It should be analyzed as a time-sensitive exposure layer that may translate psychosocial vulnerability or coping capacity into measurable physiological variation.[1,3,4,10,11]

The implication for future protocols is concrete. SOC and lifestyle questionnaires should be administered close to the physiological acquisition window rather than months apart. Wearable-derived sleep or cardiorespiratory metrics should be linked to specific academic periods, such as examination weeks, clinical training blocks, or ordinary class weeks. Salivary sampling should be scheduled in relation to the same stressor window. Without this temporal alignment, multimodal designs risk combining variables that are conceptually related but empirically asynchronous.

Parallel evidence: wearables, sleep, and cardiorespiratory endpoints

The wearable literature provides strong methodological reasons to expand beyond self-report while also defining the limits of objective monitoring. A recent systematic review and meta-analysis of wearable artificial intelligence for stress detection in students reported promising classification performance, but also emphasized small samples, variable risk of bias, differences in ground truth, device placement, and limited readiness for direct clinical or academic implementation.[8]

Specific student studies support the usefulness of objective sleep and cardiorespiratory metrics. Wearable sleep data have been used to predict stress in first-year college students, and biometrically measured sleep in medical students has been associated with psychological health and academic experiences.[10,11] These findings are relevant because sleep is both a lifestyle exposure and a physiological endpoint. Nevertheless, their interpretability depends on the acquisition window, missing data, device model, proprietary algorithms, and whether the reported endpoint represents a transparent physiological metric or a vendor-generated composite score.

Comparability remains the central issue. Wrist-worn protocols can be feasible in educational environments, and passive sensing can increase ecological validity, but interpretation is weakened when studies differ in stress tasks, self-report labels, sampling frequency, preprocessing, feature extraction, and validation strategy.[9,14-17] Transparent endpoints such as total sleep time, resting heart rate, HRV, respiratory rate, or electrodermal activity are not equivalent to closed stress, readiness, or recovery scores generated by commercial devices. Both may be useful, but they must be reported and interpreted separately.

Salivary biomarkers in student stress research

Salivary biomarkers add a biological layer to stress phenotyping because they are non-invasive and feasible in student populations. Recent dental-student studies have used salivary cortisol across periods of higher and lower academic demand and have explored total antioxidant capacity as an additional marker of physiological burden.[12,13] These studies show how biological sampling can be incorporated into educational research without requiring invasive procedures.

However, these biomarkers do not provide context-free evidence of stress. Cortisol is strongly influenced by circadian rhythm, awakening response, sampling time, acute activity, food intake, caffeine, medication use, sleep on the previous night, smoking, and the interval between stressor and collection. Oral conditions, recent oral hygiene procedures, gingival bleeding, hydration, storage, centrifugation, assay procedures, and freeze-thaw cycles may also affect interpretation. Total antioxidant capacity is similarly sensitive to biological and methodological variability.[12,13]

The most balanced interpretation is therefore that salivary biomarkers can enrich student-stress research when they are protocolized and temporally anchored, but they should not be treated as superior to behavioral or psychometric data by default. Their value increases when they are collected alongside SOC, lifestyle, stress-label documentation, and transparent wearable endpoints within the same observation period.

Stress labels, predictive models, and personalization

The quality of any stress-prediction model depends on the label used as ground truth. Models trained on laboratory stress tasks, examination periods, ecological momentary assessment, questionnaire thresholds, or participant self-reports are not predicting exactly the same construct. A smartwatch-based comparison of stress-prediction models showed that model behavior changes when physiological signals are paired with laboratory stress labels versus participant self-reports.[16]

Passive-sensing research in college students reached a similar conclusion. The UStress study highlighted that subjective stress fluctuates with context and user profile, which makes personalization and contextual modeling more defensible than generic classifiers.[15] Reviews of wearable stress detection reinforce that performance estimates cannot be interpreted from accuracy values alone; they must be read together with sensor type, population, temporal window, label definition, validation strategy, and handling of interindividual variability.[8,14,17]

These findings directly affect the proposed framework. If SOC and lifestyle are expected to explain variation in physiological stress, the outcome label must be explicit. A study using exam week as the stressor, a study using daily self-reported stress, and a study using a laboratory arithmetic task are not interchangeable. Each design may be valid, but each supports a different inferential claim.

Implementation, acceptability, and participant burden

Real-world usefulness also depends on whether students can tolerate and sustain the protocol. Sensor-supported interventions and reviews of in-the-moment detection show that acceptability, usability, adherence, attrition, and burden influence both effectiveness and data quality.[18,19]

From conceptual framework to operational protocol

The proposed framework, summarized in **Table 1** , can guide future empirical studies if it is translated into minimum design decisions. A first step is to select the stressor window, such as ordinary academic routine, examination week, clinical training, or a predefined laboratory task. A second step is to define the label, such as perceived stress score, ecological momentary assessment, exam calendar, or experimental condition. A third step is to align SOC, lifestyle, wearable, and salivary data to that same window. A fourth step is to report missing data, wear time, sampling deviations, and participant burden.

Variables should be prioritized according to interpretability. SOC may be measured using a validated SOC scale; lifestyle should include sleep, physical activity, diet or meal regularity, substance use, and routine stability; wearable endpoints should favor transparent metrics such as total sleep time, sleep efficiency, resting heart rate, HRV, respiratory rate, or electrodermal activity; salivary endpoints may include cortisol and, where justified, oxidative or inflammatory markers. Proprietary scores may be reported descriptively, but they should not replace transparent endpoints or be treated as interchangeable across devices.

KEY TABLE OR COMPARATIVE SUMMARY

Table 1. Evidence tiers supporting the integration of salutogenic resources, lifestyle, and objective stress measurement in university students.

Evidence tier	Domain	Representative studies	Analytical contribution	Main limitation for the proposed framework
Direct evidence	SOC, lifestyle, and student mental health	Ferdinandi-Coelho et al. (1); Dadaczynski et al. (2); Braga et al. (3); Silva & Vettore (4)	Supports associations among stronger SOC, healthier lifestyle profiles, academic context, well-being, and lower psychological distress in university students.	Predominantly self-reported and cross-sectional; does not directly establish physiological pathways.
Parallel evidence	Wearable AI and stress detection in students	Abd-alrazaq et al. (8); Arriba-Perez et al. (9)	Shows feasibility and promise of wearable-supported stress detection in student settings.	Performance depends on device placement, sample size, stress classes, ground truth, and risk of bias.
Parallel evidence	Sleep and cardiorespiratory metrics	Bloomfield et al. (10); Oberleitner et al. (11)	Indicates that objective sleep and biometric signals may relate to stress and academic experience.	Requires temporal anchoring, transparent endpoints, and careful treatment of proprietary algorithms.
Parallel evidence	Salivary biomarkers	Spiljak et al. (12); Bolos et al. (13)	Demonstrates feasible use of cortisol and total antioxidant capacity in student stress research.	Interpretation is highly dependent on circadian, oral-health, behavioral, and laboratory control.
Parallel evidence	Passive sensing, modeling, and label definition	Gradl et al. (14); Egilmez et al. (15); Dai et al. (16); Gedam & Paul (17)	Clarifies the importance of sensor choice, feature extraction, personalization, and stress-label definition.	Heterogeneous labels and pipelines limit comparability and external validity.
Implementation evidence	Sensor-supported monitoring and intervention	Millings et al. (18); Dobson et al. (19)	Shows that acceptability, burden, adherence, and in-the-moment intervention design affect real-world usefulness.	Feasible protocols may still fail if wear time, attrition, and participant burden are not reported.

Critical appraisal of the field

Where the evidence converges

The strongest convergence is not a demonstrated causal chain, but a coherent methodological problem. SOC and lifestyle studies show that student vulnerability is partly organized by psychosocial resources and behavior.[1-4] Wearable and biomarker studies show that physiological stress-related signals can be measured with increasing temporal resolution.[8-17] Implementation studies show that these measures remain dependent on adherence, acceptability, and burden.[18,19] Together, these lines justify multimodal research, but only under explicit methodological controls.

A second convergence concerns construct separation. SOC is a salutogenic resource; lifestyle is a modifiable behavioral exposure; perceived stress is a subjective appraisal; wearable signals are physiological or algorithmically derived measurements; and salivary biomarkers are protocol-dependent biological endpoints. Treating these layers as complementary but distinct, rather than interchangeable, can make future studies more interpretable.

Where the evidence remains weak

The principal weakness is the shortage of direct multimodal studies that measure SOC, lifestyle, wearable-derived endpoints, salivary biomarkers, and stress labels in the same university-student cohort. Current evidence supports parts of the framework but not the full pathway. Therefore, any claim that stronger SOC produces a specific wearable or salivary phenotype should be considered premature.

A second weakness is the instability of stress labels. Academic stress, perceived stress, laboratory stress, examination stress, acute anxiety, chronic strain, and poor sleep may overlap but are not identical. Without a declared label and observation window, physiological outputs can become difficult to interpret, even when sensors are technically reliable.

A third weakness is reporting heterogeneity. Device model, sampling frequency, signal loss, preprocessing, feature extraction, saliva collection timing, fasting status, medication use, storage, assay procedures, adherence, and missing data are often insufficiently reported. This limits reproducibility and makes it difficult to compare findings across studies.

Operational research agenda

A practical future study could use a longitudinal design across ordinary academic weeks and examination weeks. SOC would be measured at baseline as a relatively stable salutogenic resource.

Lifestyle variables would be measured repeatedly or summarized within the same week as the physiological data. Wearable endpoints would prioritize transparent sleep or cardiorespiratory measures. Salivary cortisol or another justified biomarker would be collected under standardized timing and handling conditions. The stress label would be declared in advance and could combine academic calendar, perceived stress, and ecological momentary assessment.

Such a design would allow three levels of analysis: first, whether SOC is associated with lifestyle organization; second, whether lifestyle and academic period are associated with physiological endpoints; and third, whether SOC contributes to physiological variation after behavioral and contextual variables are considered. This would transform the current framework from conceptual integration into a testable research model, whose minimum methodological conditions are outlined in **Table 2.**

Table 2. Minimum methodological agenda for reproducible multimodal studies on SOC, lifestyle, and objective stress phenotyping in university students.

Element	Problem addressed	Minimum recommendation	Basis of recommendation
Review transparency	Narrative reviews may appear selective.	State information sources, search window, descriptor blocks, representative search combinations, inclusion/exclusion criteria, and rationale for methodological representativeness.	Narrative-review transparency principles and author synthesis.
Temporal alignment	Questionnaires, academic events, biosignals, and saliva may refer to different windows.	Collect SOC, lifestyle, stress labels, wearable data, and biomarkers within defined and timestamped observation windows.	Direct student evidence plus integrative synthesis.
Stress-label definition	Models trained on different stress proxies predict different constructs.	Declare whether the label comes from laboratory task, exam calendar, EMA, questionnaire, naturalistic event, or combined strategy.	Parallel modeling and wearable evidence.
Transparent endpoints	Closed device algorithms reduce comparability.	Report raw or near-raw metrics such as total sleep time, sleep efficiency, resting heart rate, HRV, respiratory rate, or EDA separately from vendor composite scores.	Parallel wearable evidence; author synthesis.
Salivary protocol	Cortisol and TAC are sensitive to timing, habits, oral conditions, and handling.	Report collection time, fasting/recent intake, caffeine, smoking, physical activity, medication, oral hygiene or bleeding, sleep, storage, processing, and assay details.	Parallel biomarker evidence.
Device and pipeline reporting	Studies become difficult to reproduce across sensors and pipelines.	Report device model, placement, sampling frequency, wear-time criteria, signal loss, preprocessing, feature extraction, and validation method.	Parallel wearable/modeling evidence.
Participant burden	High-intensity protocols may reduce adherence and distort ecological validity.	Report effective wear time, missing data, attrition, scale completion, participant burden, and acceptability.	Implementation evidence.
Multimodal parsimony	Accumulating sensors may not improve interpretation.	Prefer lean combinations: SOC, core lifestyle variables, one transparent sleep or cardiorespiratory endpoint, one justified biomarker, and one explicit stress label.	Author integrative synthesis grounded in reviewed limitations.

Conclusion

Clinical interpretation.

Current literature supports the relevance of sense of coherence, lifestyle, and wearable-derived physiological measures for understanding psychological distress and health-related behavior in university students. These domains are clinically and methodologically relevant, but the available evidence should be interpreted as associative and hypothesis-generating rather than as proof of a validated causal pathway.

Evidence limits and methodological discipline.

The most cautious interpretation is that salutogenic resources may influence physiological stress indirectly through coping, behavioral organization, sleep, activity patterns, and exposure to academic demands. Salivary biomarkers and wearable-derived outputs are informative only when acquisition, labeling, preprocessing, device context, and environmental conditions are explicitly reported.

Future validation pathway.

The main contribution of the present review is methodological. It proposes an evidentiary hierarchy and a minimum operational agenda for multimodal student-health studies in which psychosocial resources, behavioral exposures, and physiological endpoints are measured within the same observation window. Under these conditions, objective stress phenotyping may move from technological promise toward reproducible, auditable, and translationally interpretable evidence.

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