Supplementary Information

S1. Inclusion and Exclusion Criteria

Table S1 presents the detailed inclusion and exclusion criteria used to screen and select studies for this systematic review.

Criterion Category	Inclusion Criteria	Exclusion Criteria
Study Type	Original research articles with full-text access	Reviews, meta-analyses, editorials, letters, conference abstracts, symposium papers
Publication Date	Published between January 1, 2015, and July 31, 2025	Published before 2015 or After July 2025
Language	English	Non-English publications
Population	Human participants (any age group)	Animal studies or in vitro studies
Sensor Modality	Studies using ECG or PPG sensors (wearable, portable, or clinical) for anxiety detection, recognition, or prediction	Studies not involving ECG or PPG sensors; studies using other sensors only (e.g., GSR, EEG, respiration)
Outcome Focus	Studies reporting physiological signal analysis related to anxiety or stress with identifiable measurement parameters	Studies not addressing anxiety or stress as a primary or secondary outcome
Data Accessibility	Full-text available via institutional or open-access sources	No access to full text (paywall without institutional access, unavailable through interlibrary request)
Study Quality	Clear methodology, analysable results, and documented measurement protocols	Insufficient methodological detail or unclear data collection/analysis procedures

S2. Methodological Limitations Rating Criteria

Table S2 presents the definitions and rating criteria for the six methodological limitations (L1-L6) used to assess the quality of included studies. Each limitation was rated as Low, Moderate, or Serious based on the criteria described below.

Code	Limitation	Low	Moderate	Serious
L1	Restricted Participant Selection	Diverse sample or justified narrow group; some subgroup reporting	Over-representation of one group (60-80%) or narrow age band; partial justification	Very narrow group without justification; excludes key populations; no generalizability discussion
L2	Repetitive Exposure Effects	Randomized order; adequate washout; <=2 repetitions	3-5 repetitions; incomplete counterbalancing; short washout	>5 repetitions or fixed order; no washout; high practice/fatigue/habituation risk
L3	Sensory Modality Restriction	Modality matches aims or multimodal used; claims limited to tested modality	Single modality but broader conclusions implied; partial rationale	Modality misaligned with conclusions; no rationale
L4	Mismatched Stimulus Duration	Duration aligns with physiological response; small deviations (<=20%)	Noticeable mismatch (0.5-0.8x or 1.2-1.5x planned); incomplete timing logs	Major mismatch (<0.5x or >1.5x planned); poor logging; invalidates features
L5	Detection Modality Constraints	Appropriate sensors; adequate sampling rate; QC present	Borderline adequacy; marginal sampling; occasional artifacts; limited calibration	Sensor/modality not fit for purpose; inadequate sampling; poor placement; high artifacts
L6	Inadequate Signal Collection Duration	Long enough for stable features, baseline & multiple trials included	Minimal but usable; few trials; short baseline	Too short for planned features; no baseline; single brief trial

S3. Summary of Included Studies

Table S3. Summary of included studies examining anxiety detection using wearable electrocardiography (ECG) and photoplethysmography (PPG). This table provides a comprehensive overview of the 38 studies included in this systematic review, detailing author information and publication year, number of participants, age range, health status, self-assessment instruments used (including the State-Trait Anxiety Inventory (STAI) and Trier Social Stress Test (TSST)), anxiety induction method, physiological detection modalities (such as electrodermal activity (EDA), electromyography (EMG), galvanic skin response (GSR), heart rate variability (HRV), respiration (RSP), remote photoplethysmography (rPPG), and accelerometer sensor (ACC)), signal acquisition sites, recording duration, features analyzed, analytical methods employed, and key findings. N/R: not reported; N/A: not applicable.

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Authors (Year)	**No. of Participants**	**Age**	**Health Status**	**Self-assessment Tests**	**Induction Method**	**Detection Method**	**Acquisition Site**	**Signal Length**	**Features Analyzed**	**Analysis Method**	**Results**
Yang et al. (2025)	18 participants (4 female, 14 male)	67.33 ± 6.71 years	Parkinson's disease patients	N/A	FOG induced via TUG test under ON/OFF medication states	ECG, GSR, IMU	IMU: feet; GSR: hands; ECG: torso	126.63 minutes	Time, frequency, nonlinear features from ECG, HR, GSR, IMU	XGBoost, SVM, KNN, Decision Trees; Bi-LSTM, TCN, ASFormer	Physiological signals did not enhance FOG detection; IMU features most effective
Gupta et al. (2024)	202 healthcare providers (100 RYM, 102 SMC)	≥ 18 years old	Healthy	DASS-21, Mini Z Questionnaire	RYM: 1-week Rajyoga + daily 30-min virtual; SMC: 1-day counseling	12-lead ECG at 500Hz	ECG machine connected to chest	10 seconds per ECG	Ultra Short HRV; Time Series features (tsfresh)	Random Forest with SMOTE	Rajyoga reduced anxiety, depression, burnout; ML predicted burnout from ECG
Baygin et al. (2024)	19 subjects (5 female)	N/R	Anxiety disorders	Hamilton Anxiety	Anxiety-inducing	ECG	Wearable sensors (site	4-6 seconds	PBP-based feature	KNN, SVM, Chi2	Classification accuracy over

				Rating Scale	videos		not reported)		extraction, wavelet transform	functions	98.5% for anxiety classification
Kiel et al. (2024)	119 children	4 years at baseline, 5-7 years at follow-up	Healthy	Mother-reported social anxiety and effortful control	Baseline and speech task for RSA measurement	ECG, Respiration	Laboratory setting, 3-Lead formation, Belt	1 hour 30 minutes	Baseline and reactive RSA, effortful control, social anxiety symptoms	Statistical analysis of RSA modulation	Effortful control buffers against social anxiety in those with low baseline RSA
Martin et al. (2024)	100 nursing professionals	N/R	Healthy	Various distress and moral distress questionnaires	VR scenarios involving morally complex decisions	ECG, EDA, pleth, RSP	VR session and wearable device monitoring	1 hour 5 minutes	Stress and moral distress response, digital phenotype profiling	Pre-post comparison, ML for digital phenotype	VR expected to elicit stress; digital phenotypes could predict distress
Campanella et al. (2024)	29 Participants (8 female)	20-60 years old	N/R	N/R	Cognitive, mental, and psychological stressors protocol	PPG, EDA (Empatica E4)	Wrist	35 minutes	N/R	Signal processing pipeline	Dataset provides insights into work/academic stress
Prajod et al. (2024)	37 participants (8 female)	18–48 years	N/R	NASA-TLX questionnaire	Simulated industrial human-robot collaboration task	ECG (Polar H10)	Chest band	1 hour	HRV temporal features, Mean heart rate, Arousal levels	Comparison of HRV between challenge conditions	Significant arousal and HR differences between boredom and higher challenges
Dal Bò et	66	N/R	Depressive	Depressive	Emotional	ECG,	Chest in	1 hour	HRV (vagal	Repeated	HRV increased

al. (2024)	participants		symptoms, social anxiety, healthy controls	and social anxiety symptoms assessed	body odors to modulate responses to neutral faces	HRV, EEG	modified lead II configuration	30 minutes	tone), ERPs, ERPSs (delta and beta power)	measures ANOVA	with emotional odors; ERPs showed higher delta and lower beta
Alshanskaia et al. (2024)	90 participants	18 to 45 years	Healthy to depression/ anxiety disorders	BDI-II, STAI, STAI-T	Cognitive 1-back task with six challenging levels	ECG, PPG	ECG: chest, PPG: fingertip/wrist	15 minutes	HRV, task accuracy, ECG and PPG heart rate changes	Correlation of physiological markers with psychological data	Higher task difficulty raised HR; anxiety linked to cardiovascular responses
Mansour et al. (2023)	36 participants	18-40 years old	Healthy	STAI-S, Visual Analog Scale	Trier social stress test (TSST)	PPG, VOCs	PPG: wrist; VOCs: underarm and breath	2 hours	HRV, cortisol levels, anxiety, breath and skin VOC fingerprinting	GC-MS sensor array, prediction model	Breath VOCs differed by stress; eight VOCs linked to stress
Lewis et al. (2023)	125 Participants (96 female)	18-55 years	PTSD symptoms	PTSD hyperarousal score, Dissociative Experiences Scale	Dark-enhanced startle paradigm, Fear conditioning	EMG, ECG, EDA	EMG: muscle groups, ECG: chest, EDA: fingers	1 minute	Fear-potentiated startle, EMG, ECG, skin conductance	Penalized regression, OLS, cross-validation	Penalized regressions improved fear extinction prediction
van Dijk et al. (2023)	57 participants	Mean age 26.70 (SD= 9.86) years	Healthy	Questionnaires (stress and anxiety)	Diaphragmatic breathing exercise (five times)	PPG, ECG	PPG: mobile phone camera, ECG: NeXus apparatus	25 minutes	RMSSD, pNN50, LF power, HF power, resonance frequency	N/R	High correlation between PPG and ECG-derived HRV indices
Vabba et al. (2023)	245 (total), 28 (HRV	N/R	General population	MAIA-2, PHQ-9,	Self-reported	PPG	Remote (via phone app)	N/R	Interoceptive accuracy,	Longitudinal statistical	Lower HRV, higher

	subsample)			STAI, PSQI	questionnaires, heartbeat counting task				HRV, MAIA-2 scores	analysis	depression, anxiety during lockdown
Dahal et al. (2023)	40 subjects	N/R	Healthy	N/R	TSST (WESAD), interruptions and time pressure (SWELL)	ACC, ECG, TEMP, RESP, EDA, EMG	Chest-worn sensors	45 minutes	SDNN, RMSSD, LF power, HF power, LF/HF ratio	mRMR, Random Forest Algorithm	Global stress RF model achieved over 99% accuracy
Rinella et al. (2022)	31 healthy adults (14 male, 17 female)	18–39 years old	Healthy	SAM, POMS, STAI-Y	Music videos	ECG, PPG	PPG: left wrist, I-Lead ECG	7 minutes	R-wave detection, IBIs for both signals	Analyzed baseline differences	PPG achieved accuracy comparable to ECG in detecting affective variables
Ritsert et al. (2022)	19 participants (14 males, 5 females)	18–56 years old	Healthy students	STAI-Y, POMS	Anxiety-inducing and non-anxiety-inducing video clips	ECG, RSP	ECG and RSP: portable device (BIOPAC)	41 minutes	HRV, BRV, MHR, SD, RMSSD, SDNN, MBR	Longitudinal mixed-effects	Significant changes in HRV and BRV between anxiety states
Ding et al. (2022)	30 participants	24.37 ± 2.16 years	No mental disorders history	Dimensional emotion ratings	Aversive pictures or risk of electric shocks	ECG, GSR	ECG: inside of both wrists, GSR: fingers	1 hour 5 minutes	R-R intervals, RMSSD, TRI, TINN, SD1, SD2, LF, HF, LF/HF	SVR, LASSO regression, ensemble of trees, LOSO	High correlation between predicted and self-reported state anxiety
Howell et al. (2022)	73 participants	18-36 years old	Varying levels of affectivity, depression,	BDI-II, BAI, PANAS	Virtual Morris Water Task	ECG	ECG on the chest	N/A	HRV, SDNN, Log-transformed SDNN	Statistical analysis of HRV and affective	Higher baseline HRV improved set-shifting; low NA enhanced

			anxiety		variant					traits	flexibility
Morales-Fajardo et al. (2022)	56 students	18-24	Healthy	STAI	Academic tasks (class, exams)	rPPG	Face (cheeks)	1-2 hours	Heart Rate Variability indices	SVM, KNN, J48 decision tree, Random Forest	96% accuracy in stress detection
Kong et al. (2022)	99 participants	N/R	Healthy with high/low trait anxiety	STAI	Evaluated speech task (preparation, presentation, recovery)	ECG, Respiration	ECG: Chest; Respiration: Chest	N/R	RR intervals, respiratory features, time/frequency-domain HRV	SVM, KNN, Random Forest, feature selection	Pattern recognition of high/low trait anxiety using autonomic features
Spinella et al. (2021)	43 Participants	≥ 19 years old	Medically healthy adults, infrequent cannabis users	CBD belief ratings, STAI-S-SF, I-PANAS-SF, B-BAES	Maastricht Acute Stress Test (MAST)	ECG	Three electrodes on chest belt	3 hours	SDNN	Generalized estimating equations, post-hoc power analysis	Expectancy of CBD led to increased sedation, HRV changes, reduced anxiety
Perpetuini et al. (2021)	102 (54 males, 48 females)	20-70 years old	Healthy	STAI-Y	Anxiety-inducing video	PPG	Brachial and radial artery	30 seconds	Log-transformed SDNN	General Linear Model, supervised learning, cross-validation	Good correlation between STAI-Y score and predicted state anxiety
Dalmeida et al. (2021)	27 participants	Young adults	Healthy	N/R	Driving protocol, relaxing music, after 8-hour work shift	ECG, EMG, GSR, respiration, Apple Watch	Apple Watch on wrist, others not specified	N/A	HRV, RR Intervals, Time/Frequency-Domain Features, GSR	RFE, Extra Trees Classifier, One-Way ANOVA, Grid Search	Achieved recall of 80% for classifying stress

Szakonyi et al. (2021)	7 participants (3 Female)	63.14 years	Healthy	STAI	TSST, Stroop Color Word Test	ECG	Right side under collarbone, left side on rib cage	2-3 days	HRV time-domain, frequency-domain, non-linear features	FFT, AR modeling, CHAID, C5, Logistic Regression, SVM, XGBoost	96.31% accuracy with 5-min overlap; 99.47% F1 participant-wise
Costa et al. (2021)	106 Participants	≥ 18 years old	Diagnosed with GAD	GAD-7, M.I.N.I., HAM-D, PSWQ	Cognitive tasks with neutral and emotional stimuli	PPG	Second and third fingers of left hand	16 hours	HRV, High-Frequency HRV, RMSSD, IBI, HRV percent variation	Regression analyses, F-statistics, MICE, LOCF	HRV flexibility predicted EI improvement in FLX group
Schwerdtfeger et al. (2021)	21 participants (9 men, 12 women)	Mean age 22.48 years	Healthy	Six-point Likert scale (closeness, valence, warmth)	Social interactions and daily life stressors	ECG, accelerometer	Chest (ECG) and body (movement sensor)	36 hours	RMSSD, Prevalence of AddHRVr triggers, Quality of interactions	Algorithm simulation and multilevel models	HRV decrease associated with lower quality social interactions
Veluswamy et al. (2020)	33	≥ 13 years old	Sickle Cell Disease vs. Control	STAI Form Y-1 and Y-2, PASS	Thermal stimulation (cold and heat) via thermode	PPG, ECG, continuous BP, respiratory waveforms	Left thumb (PPG), chest (ECG), finger, thorax/abdomen	45 minutes	MBF changes, vasoconstriction, HRV, LFP, HFP, LHR	Cross-correlation, t-test, Wilcoxon, repeated-measures ANOVA	SCD patients showed greater vasoconstriction, faster response
Ihmig et al. (2020)	57 individuals	Ages 18-40	Spider-fearful individuals	Subjective Ratings of Arousal	Spider Video Clips	ECG, EDA, RSP	ECG: lead II, EDA: palm, RSP: chest strap	21 minutes	HR, NNI, avNN, sdNN, rMSSD, NN50, pNN50, pNN20; EDA features	Decision Trees, Discriminant Analysis, KNN, SVM, Naïve Bayes	89.8% accuracy for two-level, 74.4% for three-level classification
Reichenber	70	N/R	35 SAD	SIAS,	Social-	Facial	ECG: upper	N/R	Heart rate,	Repeated	FPE measures

ger et al. (2019)	participants		patients, 35 healthy controls	SASKO, BDI-II, BFNE-R, FPES	evaluative video clips	EMG, ECG	sternum and lowest rib; EMG: brow and cheek		corrugator EMG, zygomaticus EMG, valence, arousal	measures ANOVA, t-tests, stepwise logistic regression	and positive video reactivity better predicted SAD
Scott et al. (2019)	51 patients, 13 nurses	Over 60 years old	Peripheral arterial disease	N/R	Observing and interviewing participants	ABPI and MPPG	ABPI: brachial artery and ankles; MPPG: multiple sites	N/R	Test discomfort, device preference	Thematic analysis	MPPG preferred for ease, speed, comfort; ABPI caused discomfort
Roy et al. (2019)	25	N/R	N/R	Emotional intensity ratings, task performance, self-report anxiety	High-arousal negative images; shoot-don't-shoot scenario	EEG, ECG	Scalp for EEG; unspecified for ECG	25 minutes	Brain connectivity, HRV, emotional intensity, anxiety	Functional connectivity analysis, correlation analyses	Lab intensity correlated with simulation anxiety; theta-band predicted HRV
Parent et al. (2019)	18 participants (4 females)	20-35 years	Healthy	STAI	Modified n-back task with aversive auditory stressors	ECG, fNIRS	fNIRS: 16-channel headband; ECG: Single lead	45 minutes	fNIRS: HbO2 and HHb; ECG: Time and frequency domain features	Naive Bayes classifier	fNIRS + ECG combination provided best accuracy for mental workload
Matthews et al. (2019)	68 undergraduate students (31 women, 37 men)	Mean age 19.3 years	Healthy	AnTI, Hardiness Scale, Short Grit Scale, DSSQ, NASA-TLX	Multi-UAS control simulation; negative feedback	EEG, ECG, fNIR, TCD sensors	EEG: frontal scalp; fNIR: forehead; TCD: temporal	1 hour	EEG spectral power, IBI, HRV, rSO2, CBFV	Repeated measures ANOVA, correlation, regression analysis	Both stressors increased distress and high-frequency EEG activity
Panitz et al. (2018)	87 right-handed	18–35	Healthy	MPQ, NEO-FFI, BIS,	CS: Neutral	EEG, ECG, GSR	EEG: 64-channel	4-6 seconds	EEG: LPP; ECG: Fear	ICA artifact removal, R-	COMT Val158Met

	males	years		ZKPQ, STAI, BAS	male faces; US: 1s white noise burst (95 dB)		scalp; ECG: left leg, right forearm; SCR: left hand	intervals	bradycardia; SCR: Log-transformed	peak detection; ANOVAs, regression, ANCOVA	affected Day 2 fear recall; fearfulness predicted initial fear
Nikolić et al. (2018)	96 children	8–12 years	Typically developing children	N/A	Singing on stage followed by inflated, noninflated, or no praise	PPG and TEMP sensor for blushing	Cheek	3 minutes	Blood pulse amplitude, blood volume, temperature changes	Comparative analysis of physiological and self-reported blushing	Inflated praise increased blushing in socially anxious children
Davies et al. (2015)	60 participants (34 CBT, 26 ACT)	Mean age 35.76 years	Anxiety disorders	MASQ, ADIS-IV	Relaxation Task; Hyperventilation Task	ECG, respiration	ECG: under right clavicle, lower right rib, left clavicle; RSP: chest/abdomen	15 hours	HRV, HF	FFT using Kubios software	Higher pre-treatment HRV associated with worse outcome
Giannakakis et al. (2017)	23 participants	N/R	Healthy	N/R	Stroop Color Word Test, mental arithmetic tasks	ECG, rPPG (facial video)	ECG: Chest; rPPG: Face (camera-based)	N/R	Eye-related events, mouth activity, head movements, HR, HRV features	ML classifiers, statistical analysis	Facial cues combined with rPPG-derived HR effectively detected stress
Jiao et al. (2023)	9 participants	N/R	Healthy workers	N/R	Hot and humid working environment	PPG, EEG	PPG: Fingertip; EEG: Scalp (5 channels); Pupil diameter	N/R	PPG features, pupil diameter, EEG signals	Quick identification model for anxiety and thermal comfort	PPG, pupil diameter, EEG together assessed workers' anxiety

S4. Database Search Strategy

A single Boolean search query was developed and applied identically across PubMed, Embase, and ScienceDirect for the period from January 2015 to July 2025. The query used was:

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(anxiety) AND (detection OR recognition OR prediction) AND (ECG OR electrocardiogram OR PPG OR photoplethysmography)
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In all three databases, the search targeted titles, abstracts, and author-supplied keywords. Filters applied were: English language, human studies, and methodology papers.

Search strings as executed in each database:

1. PubMed:

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(anxiety) AND (detection OR recognition OR prediction) AND (ECG OR electrocardiogram OR PPG OR photoplethysmography)
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Filters: English, Humans, Methodology; publication date January 2015-July 2025.

2. Embase:

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(anxiety) AND (detection OR recognition OR prediction) AND (ECG OR electrocardiogram OR PPG OR photoplethysmography)
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Filters: English language, Humans, Methodology; publication year January 2015-July 2025.

3. ScienceDirect:

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(anxiety) AND (detection OR recognition OR prediction) AND (ECG OR electrocardiogram OR PPG OR photoplethysmography)
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Filters: English language, Humans, Methodology; year range 2015-2025.

These search strings were designed to ensure a consistent and reproducible strategy across databases.