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PASSIVE SENSING AND WEARABLES FOR BURNOUT-RELATED OUTCOMES IN HEALTH CARE WORKERS: A STRUCTURED NARRATIVE REVIEW OF DIGITAL BIOMARKERS, IMPLEMENTATION BARRIERS, AND ETHICAL GOVERNANCE

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ABSTRACT

Burnout in health care workers is usually monitored through intermittent self-report instruments, which makes early recognition of occupational distress difficult and often delays intervention. Wearables, smartwatches, and other forms of passive sensing offer a more continuous approach to tracking sleep, physiological stress, activity, and recovery patterns that may precede clinically relevant deterioration in well-being. This structured narrative review synthesizes current evidence on passive sensing and wearable technologies for burnout-related outcomes in health care workers, with particular attention to digital biomarkers, implementation barriers, organizational moderators, and ethical governance. The review corpus combines direct sensing studies in physicians, residents, and nurses with contextual literature on workplace interventions, resilience, documentation burden, digital phenotyping ethics, and workplace biosensors. Current direct evidence remains limited. Existing studies do not yet support a stable physiological biomarker of burnout itself. Stronger and more consistent signals appear for acute stress, depressive trajectories, resilience-related patterns, sleep disruption, and recovery. A randomized clinical trial suggests that smartwatch-supported self-monitoring may improve physician burnout and resilience, while feasibility research shows that adherence depends heavily on device fit, workflow compatibility, and perceived personal value. Overall, wearables appear more mature as tools for monitoring stress, sleep, and resilience than for directly predicting burnout. Their future value will depend on stronger reporting standards, integration of workplace-context data, and transparent, non-punitive governance that prioritizes trust.

KEYWORDS

Digital Phenotyping, Health Care Workers, Wearable Devices, Burnout, Passive Sensing, Workplace Mental Health

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1. Introduction

Burnout remains one of the most persistent and strategically important threats to the health care workforce because it undermines individual well-being, team functioning, continuity of care, and organizational stability at the same time. Barac et al. (2024) note that burnout symptoms affect a substantial proportion of physicians, nurses, residents, and medical students, while Dyrbye et al. (2025) point out that in a 2022 national study, 63% of US physicians experienced burnout. These rates matter not only because burnout is distressing for workers, but because physician and nurse distress has been linked in the broader literature reviewed by Barac et al. (2024) to medical errors, reduced clinical effort, turnover, and impaired access to care. Burnout is therefore best understood not as a narrow personal problem, but as a health system problem that threatens safety, quality, and workforce sustainability (Barac et al., 2024; Dyrbye et al., 2025).

Traditional monitoring approaches are poorly matched to the temporal dynamics of occupational distress. Most organizations still rely on periodic surveys, retrospective self-report measures, or one-off well-being programs that capture how workers feel after a problem is already established. Yet the lived experience of fatigue, strain, low mood, and recovery failure is not static. It fluctuates with work hours, night shifts, patient acuity, documentation burden, educational responsibilities, workflow changes, and interruptions in team support. By the time distress becomes visible in an annual survey, meaningful opportunities for prevention may already have been lost. This is precisely why wearables and passive sensing have attracted interest: they offer the possibility of gathering repeated, minimally obtrusive data on sleep, physiological stress, activity, and recovery during real clinical life rather than after the fact (Adler et al., 2021; Barac et al., 2024).

These developments sit within the broader field of digital phenotyping. In the language used by Tomičić et al. (2022), digital phenotyping refers to the use of connected digital devices and their data streams to assess health, behavior, and well-being. Shen et al. (2022) describe an even deeper form of phenotyping that can combine digital monitoring with other biological or clinical data to generate rich, longitudinal, individual-level

profiles. In practical terms, the attraction of digital phenotyping for occupational health is obvious. Continuous or near-continuous streams of data might reveal patterns of sleep loss, physical inactivity, tachycardia, stress reactivity, mood instability, or disrupted recovery before they become clinically or professionally severe. Wearables, therefore promise more than simple measurement. They raise the possibility of earlier recognition, individualized feedback, and targeted support in environments where workers often have little time for formal mental health assessment (Shen et al., 2022; Tomičić et al., 2022).

However, the idea that burnout can be "detected" from the wrist must be approached cautiously. Burnout is a multidimensional occupational syndrome rather than a single physiological event. It emerges from a prolonged mismatch between demands and resources, and it is shaped by supervision, autonomy, role clarity, work-home conflict, staffing, educational pressure, workflow fragmentation, and digital administrative load. Evidence from a national survey of US internal medicine trainees during the COVID-19 period illustrates this clearly. St-Pierre et al. (2023) found that 76% of respondents reported disruption in their clinical schedule, 71% reported decreases in didactic conferences, 56% reported reduced protected educational time, 41% reported less direct supervision, and 81% reported worsening burnout. These findings reinforce the point that distress signals from wearables cannot be interpreted apart from the organization of work itself (St-Pierre et al., 2023).

The same message appears in reviews of workplace interventions and resilient adaptation. Cohen et al. (2023) identified a broad workplace well-being literature in health care, but most interventions remained directed at the individual rather than at the organization. Knutsen Glette et al. (2023), synthesizing 47 studies on health care professionals' adaptations during the COVID-19 pandemic, identified poorly defined workflows, limited guidance, heavier workload, and rapid digital change as major triggers for adaptation. Moy et al. (2021), in turn, showed that documentation burden linked to electronic health records is both important and poorly standardized, with 35 included studies using multiple overlapping constructs and measurement approaches. If burnout-related sensing is to be meaningful, it must connect biological and behavioral data to the structure of clinical work, not replace that context with a simplified technologic narrative (Cohen et al., 2023; Knutsen Glette et al., 2023; Moy et al., 2021).

Finally, any workplace application of passive sensing raises ethical, legal, and social questions that are central rather than peripheral. Tomičić et al. (2022) show that the literature on digital phenotyping is dominated by concerns about privacy, data security, consent, lack of regulation, data ownership, adoptability, and inequality; the authors propose trust as an umbrella theme linking these concerns. Shen et al. (2022) similarly argue that existing ethical guidance is insufficient for deep phenotyping and propose a 20-question checklist across six domains ranging from consent and equity to return of results and duties to warn. In workplace settings, Tindale et al. (2022) demonstrate that potential users and implementers are simultaneously interested in biosensors and concerned about privacy, oversight, disclosure, and data ownership. This means that passive sensing in health care cannot be judged only by whether it works technically. It must also be judged by whether it is fair, transparent, voluntary, proportionate, and trustworthy (Shen et al., 2022; Tindale et al., 2022; Tomičić et al., 2022).

Against this background, the aim of the present review is to synthesize current evidence on passive sensing and wearable technologies for burnout-related outcomes in health care workers. More specifically, the review addresses four interrelated questions: first, what direct evidence currently exists linking wearable or passive sensing data with burnout, stress, sleep, depressive symptoms, anxiety, or resilience in health care workers; second, which digital data streams appear most promising and which remain weak or inconsistent; third, what practical barriers influence feasibility, adherence, and implementation in clinical settings; and fourth, what ethical and governance conditions should be in place before such technologies are adopted more widely in the workplace.

2. Methodology

This article was designed as a structured narrative review with scoping logic. The choice of this design was deliberate. The available literature on wearables and passive sensing for burnout-related outcomes in health care workers remains small, methodologically heterogeneous, and conceptually split between direct sensing studies, intervention trials, implementation studies, organizational well-being literature, and ethics-oriented scholarship. Under these conditions, a narrative synthesis that is explicit about scope, eligibility logic, and analytical domains provides a more accurate representation of the field than a forced quantitative aggregation. The objective was therefore to produce a manuscript that is publication-style, analytically transparent, and appropriately cautious about what the current evidence can and cannot support.

The source corpus was assembled from full-text studies retrieved during topic-focused article identification in PubMed and from directly relevant full texts selected to support a coherent review of the topic. Search logic centered on combinations of terms related to digital phenotyping, passive sensing, wearable devices, smartwatches, burnout, stress, sleep, resilience, physicians, nurses, residents, workplace monitoring, and ethics. Because the article was developed as a structured review rather than a *de novo* multi-database systematic review with independently duplicated screening and protocol registration, the manuscript does not present itself as a PRISMA-compliant systematic review. Instead, the methods are reported in a way that permits readers to understand how the evidence base was selected and interpreted.

Two evidence layers were used. The first layer consisted of direct evidence: studies that involved physicians, nurses, residents, medical trainees, or other health care workers and used wearable devices, smartwatches, or passive sensing strategies to examine burnout, stress, sleep, depressive symptoms, anxiety, or resilience. The second layer consisted of contextual evidence: studies and reviews that clarified organizational drivers of distress, workplace interventions, documentation burden, resilience in clinical systems, workplace biosensor acceptability, and ethical, legal, or social issues relevant to digital phenotyping. This layered strategy was necessary because the direct sensing literature remains too limited to support a meaningful publication-length discussion without the contextual literature needed to interpret implementation and governance challenges.

Studies were prioritized when they met at least one of three criteria. First, they directly linked wearable or passive sensing data with burnout-related outcomes in health care workers. Second, they provided empirical information about feasibility, adherence, or clinician-facing design in real clinical environments. Third, they addressed organizational conditions or ethical governance issues that would plausibly shape the future deployment of passive sensing in the health care workplace. Non-empirical commentaries were not used as core evidence in the Results section, although conceptual arguments from empirical viewpoints were occasionally used in the Discussion where they clarified governance implications.

The final narrative corpus included 12 core articles. Five were classified as direct evidence: Barac et al. (2024), Marek et al. (2019), Adler et al. (2021), Agarwal et al. (2024), and Dyrbye et al. (2025). Seven were classified as contextual evidence: St-Pierre et al. (2023), Cohen et al. (2023), Knutsen Glette et al. (2023), Moy et al. (2021), Tomičić et al. (2022), Shen et al. (2022), and Tindale et al. (2022). Although this is a modest number of sources, the corpus was intentionally designed to cover the major domains needed for a journal-ready synthesis: direct biomarker evidence, implementation feasibility, organizational context, and ethical governance. Table 1 summarizes the review design, evidence layers, and synthesis framework used in the present article.

For each included article, data extraction focused on study type, setting, sample, device or digital data stream, target outcomes, duration of observation, main findings, and implementation or governance implications. The analysis was then organized into six synthesis domains: (1) the size and character of the direct evidence base; (2) the types of digital measures currently used; (3) what the literature supports regarding burnout, stress, sleep, depressive symptoms, and resilience; (4) implementation and adherence challenges; (5) organizational moderators that shape interpretation; and (6) ethical, legal, and social governance. This framework was chosen to align with the interdisciplinary scope of IJITSS, which emphasizes not only innovation but also the relationship between technology and society.

A formal study-by-study risk-of-bias appraisal was not undertaken for every paper in the present review because the corpus included heterogeneous article types, including a scoping review, a randomized clinical trial, a pilot feasibility study, a national survey, a systematic review, a qualitative meta-synthesis, a scoping review on documentation burden, and ethics-oriented evidence syntheses. Nevertheless, methodological quality was considered during interpretation. For example, Barac et al. (2024) report that all 10 direct studies in their scoping review were rated as good or high quality on the Newcastle-Ottawa Scale, yet most still lacked long-term follow-up, large samples, comparison groups, or adequate reporting of adherence and sampling frequency. These caveats were integrated into the interpretive discussion rather than treated as a separate numerical score.

The review's core interpretive model is shown in Figure 1. It depicts the article's guiding assumption that wearable data are most informative when placed between workplace context and burnout-related outcomes, rather than interpreted as self-sufficient indicators. The model also highlights that ethical governance sits around the entire process rather than at its endpoint.

Table 1. Review design, evidence layers, and synthesis framework

Domain	Operationalization in the present review
Review design	Structured narrative review with scoping logic and publication-oriented synthesis.
Direct evidence layer	Studies in health care workers using wearable devices, smartwatches, or passive sensing to examine burnout, stress, sleep, depressive symptoms, anxiety, or resilience.
Contextual evidence layer	Studies addressing workplace interventions, organizational resilience, documentation burden, ethics, law, privacy, and workplace biosensor governance.
Core corpus	12 full-text articles: 5 direct sensing studies/reviews and 7 contextual studies.
Primary extraction fields	Study type, sample, setting, technology used, target outcomes, duration, principal findings, and implementation/governance implications.
Synthesis domains	Direct evidence base; digital measures; burnout-related outcomes; implementation and adherence; organizational context; ethics and governance.
Methodological caution	No claim of a de novo PRISMA systematic review; quantitative meta-analysis judged inappropriate because of heterogeneity of devices, populations, outcomes, and study designs.

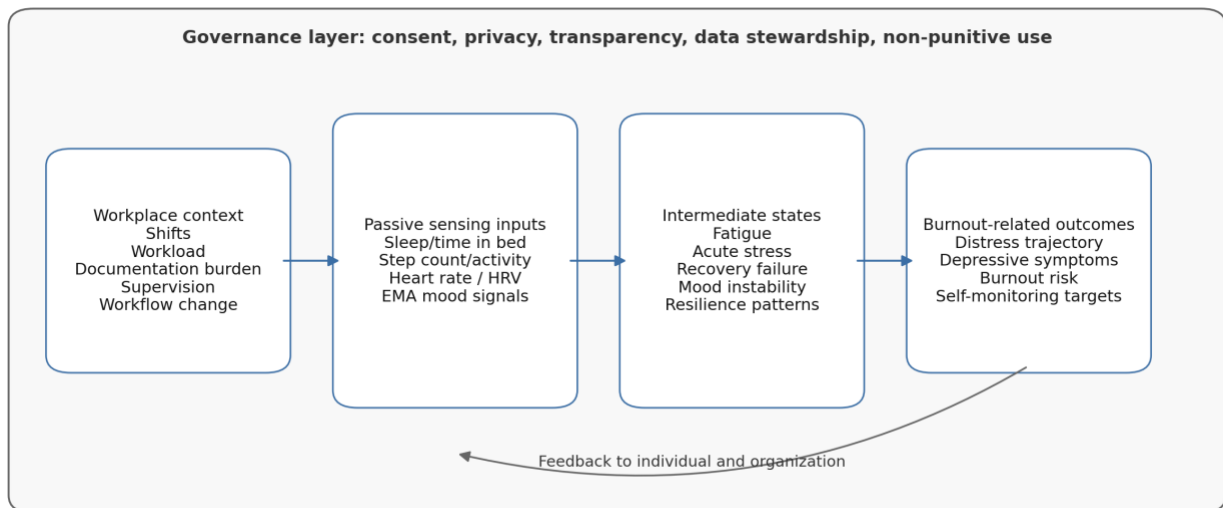


Fig. 1. Conceptual model linking workplace context, passive sensing inputs, intermediate states, and burnout-related outcomes. The model reflects the review's core argument that wearable data should be interpreted within organizational and ethical context rather than treated as self-sufficient signals.

3. Results

3.1. The direct evidence base is small, concentrated, and methodologically uneven

The most immediate finding from the literature is how small the direct evidence base actually is. In the first scoping review dedicated specifically to wearables for burnout and well-being in health care professionals, Barac et al. (2024) identified 505 records but included only 10 studies. Most were observational cohort studies, most used wrist-worn biosensors, and most were conducted in the United States. Only three direct studies in the underlying literature had more than 100 participants, and only five collected data for more than 10 weeks. These characteristics are important because they show that the field is still in an early developmental stage. Interest in the topic is high, but the number of mature longitudinal or interventional studies remains low.

The direct evidence available to the present review reflects this same pattern. Among the five direct studies or reviews included here, there is one scoping review, one small resident cohort study, one large passive sensing and ecological momentary assessment study in interns, one pilot feasibility study in emergency clinicians, and one randomized clinical trial. This is a notable spread of designs, but it also means that the literature is answering different questions at once: one set of studies asks whether certain physiological or behavioral signals correlate with distress, another asks whether digital feedback may improve well-being, and a third asks whether clinicians will even use the devices consistently in real practice. A publication-ready synthesis must keep these questions distinct.

Another recurring feature of the direct evidence base is the dominance of proxy outcomes over burnout itself. Wearables capture sleep, activity, heart rate, heart rate variability, and sometimes temperature or electrodermal measures far more naturally than they capture emotional exhaustion, depersonalization, or reduced professional accomplishment. Accordingly, direct studies often use burnout questionnaires alongside wearable data, but the wearable signal is typically closer to acute stress, sleep disruption, or behavioral change than to the full occupational syndrome. Core direct studies included in the present review are summarized in Table 2, which organizes the evidence by population, device, and principal contribution.

Table 2. Core direct evidence on wearables and passive sensing in health care workers

Study	Population and design	Digital data streams	Main contribution to the present review
Barac et al. (2024)	Scoping review of 10 studies from 505 records; physicians, nurses, residents, and medical students.	Primarily wrist-worn devices; sleep, step count, HR, HRV, temperature, and other physiological variables.	Anchor review showing that direct evidence is limited; no reliable physiological biomarker of burnout or anxiety; stronger signals for depressive symptoms and acute stress; major reporting gaps in adherence and sampling frequency.
Marek et al. (2019)	Resident cohort (n = 28) using repeated surveys and tracker data.	Fitbit-derived activity, time in bed, time asleep, awakenings, active time, resting heart rate, and call load.	No significant association between objective sleep/activity/call load and self-reported burnout; higher resting heart rate in residents with burnout symptoms; illustrates the limits of simple one-device biomarker models.
Adler et al. (2021)	Large internship cohort (n = 775) combining passive sensing with ecological momentary assessment.	Step count distributions, time in bed, sleep, heart rate, and repeated mood measures.	Most informative direct evidence for resilience-related trajectories; three multivariate indicators (lower step-count skew, greater time in bed, higher mood) associated with stress-resilience.
Agarwal et al. (2024)	6-week pilot in emergency nurses and resident physicians (n = 20).	WHOOP-derived recovery, heart rate variability, sleep performance, and stress-oriented platform metrics plus survey data.	Key feasibility study showing mixed enthusiasm, only partial routine use, role-specific engagement differences, and strong influence of device fit and user experience on adherence.

Study	Population and design	Digital data streams	Main contribution to the present review
Dyrbye et al. (2025)	Randomized clinical trial in physicians (n = 184).	Smartwatch-derived physiological data, including sleep, steps, and heart rate, with participant access to the data.	Most robust interventional evidence; smartwatch use with access to data was associated with lower adjusted odds of burnout and higher resilience at 6 months.

3.2. Current sensing approaches capture activity, sleep, heart rate, heart rate variability, and mood-adjacent data

Across the direct literature, the most common wearable signals are sleep-related measures, step count or broader activity measures, and heart rate-derived variables. Barac et al. (2024) report that sleep was the most common physiological domain in the 10 studies included in their scoping review. Devices included multiple wrist-worn systems such as Fitbit and WHOOP, as well as other wrist biosensors and, in one study, an adhesive patch. These devices combine accelerometry, optical heart sensing, and platform-derived behavioral summaries that are then compared with validated burnout, stress, depression, or anxiety scales.

Marek et al. (2019) illustrate the typical early-generation study design in this area. Residents wore Fitbit Charge HR devices, and the investigators linked measured activity, resting heart rate, time in bed, time asleep, awakenings, and other sleep variables with repeated self-reported burnout and wellness measures. The technological appeal of such studies is obvious: data are inexpensive to collect, longitudinal, and minimally disruptive. But the conceptual challenge is also evident. Fitbit-derived sleep and activity metrics are blunt indicators that may be influenced by call burden, lifestyle, gender, body composition, baseline fitness, shift schedules, device compliance, and numerous other factors that do not map neatly onto burnout.

Adler et al. (2021) move beyond this simple design by combining passive sensing with smartphone-delivered ecological momentary assessment in a much larger cohort of 775 medical interns. Their framework is particularly important because it does not reduce digital phenotyping to physiology alone. Instead, it treats resilience as a process that can be reflected in step count distributions, time in bed, heart rate, sleep, and repeated mood assessments. This multi-stream approach is closer to the reality of burnout-related distress, which unfolds behaviorally, emotionally, and physiologically over time rather than in one data channel.

Agarwal et al. (2024) provide another important perspective by examining emergency nurses and resident physicians using a WHOOP device. Their pilot highlights that the data streams generated by modern wearables are not inherently self-explanatory. Step count, sleep performance, recovery score, heart rate variability, and stress-oriented platform metrics can all be displayed to participants, but their usefulness depends on whether the wearer understands the data, trusts the platform, and feels that the information is relevant to life and work. Thus, the meaning of a signal is not only physiological; it is also shaped by the design of the interface and the user's relationship to it.

3.3. Objective wearable measures do not yet constitute a stable biomarker of burnout itself

The strongest and most consistent conclusion from the direct evidence is that there is not yet a reliable physiological biomarker of burnout. Barac et al. (2024) explicitly report that the direct studies they reviewed did not identify any reproducible physiological signal that consistently tracked burnout or anxiety. This is arguably the single most important finding in the current field because it guards against overstatement. The promise of wearables is real, but the evidence does not justify the claim that burnout can already be detected from a standard consumer device with sufficient confidence for clinical or organizational decision-making.

Marek et al. (2019) provide a good example of why this caution is necessary. In their resident cohort, there was no significant association between objectively measured sleep, call volume, or activity and self-reported burnout. High call loads were not significantly associated with burnout, training satisfaction, emotional exhaustion, or sleep quality. Likewise, measured sleep variables such as time in bed, time asleep, awakenings, and sleep latency showed no significant relationship with burnout. The authors also found no significant association between objectively measured activity and burnout. Taken together, those results show that simply adding wearable data to a residency cohort does not automatically produce an informative burnout signal.

At the same time, the Marek study should not be read as evidence that wearables are useless. The study also found that resting heart rate was significantly higher in residents experiencing burnout symptoms, and female residents were more likely to report burnout. This nuance is instructive. It suggests that single physiological measures may carry partial or subgroup-specific information without becoming a complete or robust biomarker. In other words, a signal may be interesting without being definitive. The problem is not that wearables detect nothing; the problem is that burnout is more complex than any one measurable stream.

This interpretation is supported by the logic of burnout itself. Emotional exhaustion, depersonalization, and reduced professional accomplishment are downstream expressions of chronic occupational stress operating within institutional contexts. A worker could sleep poorly and remain engaged, or sleep adequately while still feeling trapped in a demoralizing workflow. Conversely, physiological stress signals may rise during demanding but meaningful work that does not produce burnout. For that reason, the current evidence supports using wearable data as one input in a broader risk picture, not as a stand-alone diagnostic solution.

3.4. Stronger signals emerge for resilience, sleep, activity, mood, and acute stress

Although direct burnout prediction remains weak, the literature is more promising for adjacent outcomes such as resilience, depressive trajectories, sleep disruption, and acute stress. Barac et al. (2024) report that lower activity and greater time spent in bed aligned with depressive symptom burden, while heart rate-based measures, including HRV, mapped more closely onto short-term stress responses. These associations are more conceptually plausible than a direct burnout signal because they operate closer to the physiological and behavioral domains that wearables actually measure.

The most sophisticated evidence in this domain comes from Adler et al. (2021). Working with 775 interns, the authors framed resilience as a process outcome and used generalized estimating equations to identify mobile sensing indicators that differentiated stress-resilient and stress-sensitive individuals. Out of 37 candidate indicators, 17 were significant in univariate analyses. After removing highly correlated indicators, three remained significant in the multivariate model: lower internship step count skew, greater time in bed, and higher mood. The interpretation offered by the authors is clinically intuitive. Less skew in hourly step counts implies that resilient individuals spent more hours with non-zero activity. More time in bed suggests better opportunity for recovery. Higher mood and lower mood variability are logically consistent with lower vulnerability to distress (Adler et al., 2021).

Adler et al. (2021) are especially valuable because they do not confuse association with causation. The authors explicitly note that their large observational dataset is not sufficient to infer that simply changing sleep or activity will necessarily produce resilience. At the same time, they show that these patterns may be useful as early warning or intervention targets. This is an important distinction for publication-quality interpretation. Passive sensing may be more useful for identifying modifiable behavioral targets or trajectories than for classifying workers into fixed categories of "burned out" versus "not burned out."

The same caution applies to heart rate and heart rate variability. In both the Barac review and the Agarwal pilot, HR and HRV emerge as plausible markers of acute physiological strain. Yet their meaning is context dependent. Elevated heart rate or reduced HRV may reflect stress, but they may also reflect physical exertion, poor sleep, caffeine use, circadian disruption, illness, or sex-related physiological variation. For this reason, HR and HRV should currently be treated as useful but non-specific markers that gain value only when combined with timing, activity context, symptom data, and workplace variables.

3.5. Wearables may serve as self-monitoring interventions as well as measurement tools

One of the most important developments in the newer literature is the shift from thinking of wearables only as measurement devices to considering them as potential interventions. Dyrbye et al. (2025) conducted a randomized clinical trial in 184 physicians and found that physicians in the intervention arm who wore a smartwatch and had access to its physiological data showed significantly lower adjusted odds of burnout at 6 months than controls after accounting for baseline score, demographics, specialty, and work hours (OR 0.46, 95% CI 0.21-0.99, $P = .046$). In the same model, resilience scores were higher in the intervention arm (parameter estimate on a 0-40 scale, 1.20 points; 95% CI, 0.11-2.28; $P = .03$). This is a major contribution because it shows that the value of a device may lie partly in what people do with the information, not only in the predictive capacity of the sensor itself.

The significance of this finding is conceptual as well as practical. If a smartwatch prompts an individual to attend to sleep regularity, physical activity, stress exposure, or recovery needs, then the device may influence burnout-related outcomes through self-awareness, reflection, or behavior change rather than through covert

detection. This matters ethically too. A self-monitoring model is easier to align with autonomy and beneficence than a surveillance model in which the employer or institution is the primary user of the data.

At the same time, Dyrbye et al. (2025) do not justify a simplistic narrative of digital rescue. The authors did not show that smartwatch use improved every dimension of well-being, and the estimated effect size for resilience was modest. The findings should therefore be understood as promising rather than definitive. Still, this study is methodologically important because it broadens the literature from passive observation toward prospective intervention and suggests that future wearable studies may need to distinguish between sensing value, feedback value, and behavior-change value.

3.6. Feasibility, adherence, and device fit are practical bottlenecks

A technically capable device is not necessarily a usable device, and usability may determine whether sensing succeeds or fails. Agarwal et al. (2024) provide a particularly valuable window into this problem. In their 6-week pilot of emergency nurses and resident physicians, baseline assessments already suggested a meaningful target population: participants reported low professional fulfillment and moderate workplace exhaustion and interpersonal disengagement. Yet despite this relevance, only half of participants routinely used the wearable across the study period.

The user experience findings in Agarwal et al. (2024) are arguably as important as the physiological data. Participants identified a desire for a device that functioned more like ordinary consumer wearables, including familiar features such as a watch face and easier daily use. Some participants found the data empowering and potentially useful, but the device and platform themselves were experienced as obtrusive. Resident physicians appeared more engaged than nurses, suggesting that role-specific preferences and workflow realities matter. This should caution researchers against assuming that one wearable ecosystem will generalize equally across clinical groups.

Barac et al. (2024) reinforce this point at a broader level by highlighting inconsistent reporting of device adherence, sampling frequency, and user experience in the direct literature. In other words, feasibility is not a side issue that comes after biomarker discovery. Feasibility shapes biomarker discovery itself. If participants remove the device, forget to charge it, distrust the app, or find the feedback meaningless, the data stream becomes fragmented and the apparent scientific signal becomes harder to interpret. Future studies must therefore treat adherence and device fit as primary methodological outcomes rather than as minor implementation notes.

3.7. Burnout-related sensing cannot be interpreted without organizational context

The contextual evidence shows that organizational conditions are not background noise; they are part of the phenomenon under study. St-Pierre et al. (2023) found widespread disruption to clinical schedules, didactics, protected educational time, and supervision among internal medicine trainees, accompanied by worsening burnout. Such findings remind us that burnout is often generated by the architecture of work. A wearable may register the consequences of that architecture in sleep loss or physiological strain, but it does not explain them by itself.

Cohen et al. (2023) make a related point from the intervention literature. In their systematic review of workplace interventions to improve well-being and reduce burnout among nurses, physicians, and allied health professionals, the authors found 33 eligible studies, of which 30 focused on individual-level interventions and only 3 on organizational interventions. Positive outcomes were reported in 29 studies, but the authors also noted methodological weaknesses, limited use of strong controls, and sparse long-term follow-up. The broader implication is that health systems may be tempted to emphasize interventions that are easy to deploy at the level of the individual worker while underinvesting in structural reforms that address the source of stress more directly.

Knutsen Glette et al. (2023) deepen this organizational perspective through a qualitative meta-synthesis of 47 studies on health care professionals' adaptations during COVID-19. They show that poorly defined workflows, limited guidance, heavier workload, and rapid shifts toward digital solutions triggered adaptation. Some adaptations improved collaboration and accelerated beneficial changes such as telehealth or new team arrangements. Others revealed weak points in system design and produced dysfunctional workarounds. For wearable studies, this means that the same physiological signal may have very different meanings depending on whether it appears in a supportive, well-led system or in an unstable environment requiring constant improvisation.

Documentation burden adds another layer to this interpretation. Moy et al. (2021) identified 35 studies on clinical documentation burden and found seven effort constructs and four time constructs, underlining how inconsistently the concept is measured. The authors also note recurring problems with generalizability, selection bias, measurement error, and lack of contextual triangulation. From the standpoint of burnout-related sensing, documentation burden matters because it can absorb cognitive and emotional resources without necessarily being visible in simple step count or sleep summaries. The contextual studies supporting this interpretation are synthesized in Table 3.

Table 3. Contextual evidence relevant to implementation, organization, and governance

Study	Evidence type	Core finding	Relevance to publication-style synthesis
St-Pierre et al. (2023)	National survey of US internal medicine trainees	High levels of schedule disruption, reduced didactics, reduced protected educational time, reduced direct supervision, and worsening burnout during the pandemic.	Shows how strongly burnout-related outcomes are shaped by educational and organizational conditions.
Cohen et al. (2023)	Systematic review of workplace interventions	Most studies targeted individuals rather than organizations; many reported positive outcomes but with design limitations and limited long-term follow-up.	Supports the argument that digital monitoring should not replace structural intervention.
Knutsen Glette et al. (2023)	Qualitative meta-synthesis	Adaptation was triggered by unclear workflows, lack of guidelines, increased workload, and digital transitions; some adaptations improved collaboration while others exposed system weaknesses.	Provides a resilience-oriented lens for interpreting sensing data within changing clinical systems.
Moy et al. (2021)	Scoping review of documentation burden	Identified 35 studies, 7 effort constructs, 4 time constructs, and recurring measurement problems and contextual gaps.	Clarifies why passive sensing should be linked to administrative and workflow burden rather than interpreted in isolation.
Tomičić et al. (2022)	Scoping review of ethical, legal, and social issues	Privacy, consent, security, lack of regulation, adoptability, inequality, and data ownership dominate the field; trust proposed as umbrella concept.	Provides the broadest interdisciplinary governance frame for digital phenotyping.
Shen et al. (2022)	Ethics viewpoint and checklist	Twenty questions across six domains: consent, equity, privacy/partnerships, regulation/law, return of results, and duty to warn/report.	Offers practical guidance that can be adapted to workforce sensing research and deployment.
Tindale et al. (2022)	Cross-sector survey on workplace biosensors (n = 344)	Benefits and risks were recognized simultaneously; privacy, excessive oversight, and data ownership were major concerns; explicit communication and consent considered essential.	Demonstrates that worker trust and transparency are core implementation requirements.

3.8. Ethical governance and workplace trust are prerequisites for implementation

The ethical literature reviewed here suggests that trust is not a soft issue added after the technical work is finished. It is the condition under which the technical work becomes socially acceptable. Tomičić et al. (2022), in a scoping review of 151 publications on ethical, legal, and social issues in digital phenotyping, identified privacy, consent, data security, lack of regulation, data ownership, and adoptability as dominant themes. The authors explicitly propose trust as the umbrella category spanning ethical, legal, social, and technical concerns. This is highly relevant to workplace sensing because employer-employee relationships already contain asymmetries of power, evaluation, and vulnerability that can magnify distrust.

Shen et al. (2022) translate these broad concerns into a practical ethics checklist for digital health research in psychiatry. Their 20 questions are organized into six domains: informed consent; equity, diversity, and access; privacy and partnerships; regulation and law; return of results; and duty to warn and duty to report. Several of these domains are directly applicable to health care workforce sensing. Researchers and implementers must know where the data travel, which third-party vendors are involved, which privacy regimes apply across jurisdictions, what counts as actionable information, and how any signal concerning self-harm, risk, or incidental health findings would be handled. A technically sophisticated wearable study that cannot answer these questions is not ready for clinical deployment.

Workplace-specific evidence from Tindale et al. (2022) confirms that these concerns are shared by potential users and implementers. In a survey of 344 respondents across several sectors, including health care, the authors found broad agreement on the potential benefits of biosensors but also broad concern regarding privacy, excessive oversight, data sharing, and disclosure of findings of possible health significance. Data ownership produced the greatest variability. More than three-quarters of respondents rated it as extremely important for employers to explain the purpose of sensing, the kinds of information generated, the circumstances of device use, and who would be permitted to access the resulting data. In their recommendations, Tindale et al. emphasize transparent communication, explicit consent, privacy protections, safe storage, third-party access control, and clear policies for incidental findings.

These findings have direct implications for burnout-related monitoring in health care workplaces. Any institutional sensing program that is not explicitly voluntary, transparent, privacy-protective, and non-punitive risks being perceived as surveillance rather than support. This would not only be ethically problematic; it would likely undermine data quality by reducing adherence, encouraging strategic non-use, and distorting the very patterns the institution hopes to understand.

4. Discussion

4.1. Principal interpretation

The central conclusion of this review is that wearables and passive sensing are currently more mature for monitoring sleep, acute stress, resilience, and distress trajectories than for directly identifying burnout itself. This judgment follows from the convergence of the direct evidence. Barac et al. (2024) found no reliable physiological measure associated with burnout or anxiety across the current direct literature. Marek et al. (2019) found no significant association between objective sleep or activity and burnout in residents. Adler et al. (2021) identified useful resilience-related signals, but those signals operated through activity, time in bed, heart rate, and mood rather than a direct burnout fingerprint. Dyrbye et al. (2025) demonstrated benefit from smartwatch use, but the pathway appears more consistent with self-monitoring and behavioral adaptation than with validated biomarker-based detection. Taken together, these findings support cautious optimism rather than technological determinism.

This distinction matters because it changes how health systems should think about digital monitoring. If a device is framed as a burnout detector, expectations become unrealistic and risks of misuse increase. If the same device is framed as one component of a broader early-warning and self-management system that can highlight sleep disruption, reduced recovery, low activity, acute stress patterns, or worsening mood-related trajectories, then both the scientific claim and the ethical posture become stronger. In other words, the present evidence supports a supportive monitoring model much more than a predictive surveillance model.

4.2. Why burnout is harder to capture than stress, sleep, or resilience

Burnout is harder to sense than acute stress because the two phenomena are not equivalent. Acute stress may register in heart rate, heart rate variability, or short-term sleep change. Burnout, by contrast, is a chronic occupational syndrome that includes emotional and cognitive dimensions shaped by meaning, role structure, autonomy, fairness, and moral experience at work. A worker might display physiological stress without burnout during an intense but meaningful rotation; another might experience profound depersonalization or futility even when sleep and activity data appear relatively stable. This mismatch helps explain why direct biomarker studies have produced modest or inconsistent findings.

The contextual literature strengthens this explanation. St-Pierre et al. (2023) show the importance of supervision, protected educational time, and humane scheduling in trainee well-being. Cohen et al. (2023) show that institutions still rely heavily on individual-level interventions even though organizational sources of stress remain powerful. Knutsen Glette et al. (2023) demonstrate that adaptation during crisis is shaped by workflow clarity, guidelines, workload, and digital transitions. Moy et al. (2021) remind us that cognitive and documentation burden is often substantial but difficult to standardize. Burnout therefore emerges at the intersection of physiology, behavior, cognition, and organizational design. Any sensing model that ignores this intersection is likely to underperform.

This helps explain why sleep and activity signals often appear stronger than burnout signals. Sleep loss, irregular time in bed, low activity, and altered heart rate are closer to the raw capabilities of current devices. They are intermediate states rather than final syndromic outcomes. For publication and practice alike, it is better to acknowledge this layered relationship than to flatten it into the claim that one wearable metric equals burnout.

4.3. The future is likely multimodal, contextual, and clinician-facing

If the field is to progress, future systems will probably need to integrate at least four layers of information: wearable-derived physiological or behavioral data, brief self-report or ecological momentary assessment, validated well-being scales, and contextual workplace variables. Adler et al. (2021) already move in this direction by combining passive data with repeated mood reports. Barac et al. (2024) explicitly call for greater integration of system-level information such as acuity and for better reporting of device adherence and sampling frequency. The next generation of studies should extend that logic to variables such as shift structure, supervision, specialty, documentation load, and work hours.

The direct interventional evidence from Dyrbye et al. (2025) also suggests that the user-facing nature of the technology may matter. When clinicians can see and interpret their own data, the device may function as a reflective tool that supports sleep hygiene, activity planning, self-awareness, or timely help-seeking. This is conceptually different from an opaque institutional platform that processes workers' data out of view. The former can be aligned with autonomy and self-care; the latter risks being experienced as extraction or surveillance. A publication-ready interpretation of the literature should make this distinction explicit because it has implications for both effectiveness and ethics.

A related design lesson comes from Agarwal et al. (2024): technologies built for measurement are not automatically built for clinicians. Device fit, user interface, ordinary daily utility, charging, comfort, and role-specific workflow all influence uptake. Emergency nurses and resident physicians did not engage with the pilot device equally, and some wanted familiar features available in consumer devices such as Apple Watch or Fitbit. This suggests that "best" sensing technology cannot be chosen solely on measurement sophistication; it must also be chosen on whether the intended users will actually wear it.

4.4. Organizational reform cannot be replaced by digital monitoring

The contextual studies make it clear that wearable monitoring should not be used as a substitute for improving work conditions. A health system that deploys sophisticated well-being technology while leaving unsafe schedules, poor supervision, fragmented workflows, or excessive documentation demands untouched risks shifting responsibility from the organization to the individual. Cohen et al. (2023) show that the intervention literature is already skewed toward individual approaches, while St-Pierre et al. (2023) and Knutsen Glette et al. (2023) illustrate how system design and crisis management shape distress directly. Wearable programs must therefore be embedded within a broader strategy that includes organizational prevention, not layered on top of avoidable structural strain.

This point also has methodological consequences. Without contextual variables, wearable findings may be misleading. The same decline in sleep duration could represent a short period of high patient acuity, an

understaffed service, repeated overnight call, or a documentation-intensive workflow spilling into home hours. Moy et al. (2021) notes that documentation burden research itself suffers from limited contextual triangulation. Future passive sensing studies should address this directly by linking device data with schedule data, role data, workload variables, and preferably some qualitative understanding of the work setting. Without that contextual layer, the biological trace risks being overinterpreted.

For publication readers, this is one of the review's most important implications: passive sensing should be framed as a complement to organizational diagnosis, not as a technological shortcut around it. The real value of sensing may lie in helping systems see the embodied consequences of their work design more clearly. But that value is lost if the technology is used to individualize what is fundamentally a systemic problem.

4.5. Ethics, law, and trust are operational requirements, not abstract concerns

The ethical literature included in this review provides unusually concrete guidance for future studies and deployments. Tomičić et al. (2022) show that privacy, data security, consent, data ownership, lack of regulation, adoptability, and inequality are already central concerns across digital phenotyping scholarship. Shen et al. (2022) go further by insisting that research teams map data flows, vendor relationships, legal jurisdictions, return-of-results plans, and duties to warn before deep phenotyping research proceeds. Tindale et al. (2022) show that potential users and implementers in workplace settings care deeply about these issues and expect explicit communication about what data are being collected, how they will be used, and who will see them.

For health care workplaces, at least five ethical principles follow from this literature. First, participation should be voluntary and free from coercive pressure. Second, intended uses of data must be explicit, stable, and understandable to the participant. Third, data minimization should be practiced: only signals with a clear purpose should be collected. Fourth, use should be non-punitive; data collected for well-being should not quietly become a tool for discipline, evaluation, or covert performance management. Fifth, governance should include policies on incidental findings, vendor oversight, third-party access, and response pathways when significant risk signals are observed. These are not aspirational extras. They are the operational conditions for trust.

Trust matters scientifically as well as ethically. If workers suspect hidden uses of the data, adherence will fall and data quality will degrade. If they do not understand the platform, they may disengage or manipulate usage. If they experience the device as supportive and transparent, the chances of sustained participation improve. In this sense, trust is not external to measurement validity; it is one of its preconditions.

4.6. Implications for future research and publication practice

The direct and contextual literature together suggest a fairly clear agenda for future research. First, the field needs longer longitudinal studies. Barac et al. (2024) note that few studies extend beyond 10 weeks and even fewer follow participants for 12 months or more. Burnout is chronic and cumulative; short windows are better at capturing acute strain than durable occupational deterioration. Second, future studies should use richer multimodal designs that combine wearable data with repeated symptom measures, role and schedule information, and organizational context variables such as documentation burden or supervision. Third, adherence and sampling frequency must be reported consistently, as should device type, algorithm dependencies, missing-data handling, and data-processing assumptions.

Fourth, future studies should pay much more attention to equity and representation. Barac et al. (2024) point out that most direct studies inadequately report race and other participant characteristics, even though access to and engagement with digital health technologies are not evenly distributed. Tomičić et al. (2022) similarly highlight inequality and adoptability as social concerns in digital phenotyping. A field that hopes to build equitable tools for workforce well-being cannot continue to generalize from narrow, convenience-based populations without stronger demographic reporting and inclusive design.

Fifth, the field needs more pragmatic intervention studies, not only correlational sensor studies. Dyrbye et al. (2025) demonstrate that intervention-oriented smartwatch research is feasible and informative. Similar pragmatic trials could evaluate whether self-monitoring feedback, structured recovery coaching, sleep-oriented nudges, or hybrid digital-human support models reduce burnout risk in targeted clinical groups. Finally, qualitative and mixed-methods work should accompany quantitative sensing research. The signals alone cannot tell us how clinicians interpret the technology, when they find it useful, why they stop using it, or what kinds of institutional safeguards make participation feel acceptable. Table 4 summarizes publication-oriented recommendations that follow directly from the reviewed evidence.

Table 4. Publication-oriented recommendations for future studies and workplace deployment

Priority domain	Minimum expectation	Rationale from the reviewed literature
Study duration	Use longer longitudinal windows whenever possible, ideally across major rotations or 6-12 months.	Short studies capture acute strain better than chronic occupational deterioration (Barac et al., 2024).
Outcome model	Differentiate burnout from adjacent constructs such as stress, sleep disruption, depressive symptoms, and resilience.	Direct evidence is stronger for related trajectories than for a stand-alone burnout biomarker (Barac et al., 2024; Adler et al., 2021).
Contextual integration	Link wearable data with schedules, role, supervision, documentation burden, workload, and workflow data.	Organizational context shapes both distress and the meaning of sensed data (St-Pierre et al., 2023; Moy et al., 2021).
Adherence reporting	Report wear time, missing data, sampling frequency, charging burden, and user experience explicitly.	Current reporting standards are inconsistent and weaken interpretation and replication (Barac et al., 2024; Agarwal et al., 2024).
Equity and representation	Report participant characteristics fully and design recruitment strategies that broaden access.	Digital health access and acceptability are not evenly distributed (Barac et al., 2024; Tomičić et al., 2022).
Governance	Require voluntary participation, explicit consent, privacy protections, and non-punitive data use policies.	Trust, privacy, and data ownership concerns are central in digital phenotyping and workplace biosensor adoption (Tomičić et al., 2022; Tindale et al., 2022).
Implementation model	Favor clinician-facing self-monitoring and supportive escalation pathways over employer-facing surveillance.	The trial evidence suggests benefit when clinicians use the data themselves, and workplace biosensor literature warns against excessive oversight (Dyrbye et al., 2025; Tindale et al., 2022).

4.7. Strengths and limitations of the present review

This review has several strengths. It integrates direct sensing studies with contextual organizational and ethical evidence rather than treating these domains as separate conversations. It also remains explicit about the distinction between monitoring burnout-related outcomes and detecting burnout itself, which helps avoid overstatement. In addition, the article was built around full-text studies rather than abstract-level impressions, enabling a more grounded synthesis of feasibility, trial design, and governance implications.

The review also has limitations. It is a structured narrative review based on a curated full-text corpus rather than a de novo systematic review with independently duplicated screening, formal protocol registration, and exhaustive multi-database searching conducted specifically for this final manuscript. The direct literature is small and largely US-based, and several contextual sources are not wearable studies per se but were included because they are necessary for interpretation. Heterogeneity across populations, devices, study durations, and outcomes precludes quantitative pooling. These limitations mean that the review should be read as an analytically rigorous synthesis of the current field rather than as a definitive meta-analytic statement.

Despite these limitations, the review remains useful because the core problem in this field is not lack of numerical precision; it is fragmentation. Direct sensing evidence, intervention evidence, workplace implementation evidence, organizational well-being evidence, and ethics evidence are often discussed in isolation. Bringing them together offers a more realistic account of what wearable sensing can currently contribute to health care worker well-being and what conditions must be satisfied before it can contribute responsibly.

5. Conclusions

Wearables and passive sensing represent a promising but still maturing approach to monitoring burnout-related outcomes in health care workers. The present review shows that the strongest current evidence does not support a stable physiological biomarker of burnout itself. Instead, the literature is more convincing for sleep disruption, acute stress, depressive trajectories, and resilience-related patterns, especially when passive sensing is combined with repeated symptom or mood data. The field's most robust interventional study further suggests that smartwatches may improve physician burnout and resilience not only by sensing physiology, but by supporting self-monitoring and reflective behavior change (Adler et al., 2021; Barac et al., 2024; Dyrbye et al., 2025).

At the same time, the review makes clear that technology alone will not solve the problem it measures. Burnout emerges within organizational conditions shaped by workload, supervision, workflow clarity, digital administrative burden, and the broader moral and educational climate of clinical work. Wearables may help reveal the embodied consequences of these conditions, but they cannot substitute for organizational reform. Their most responsible future use lies in complementing, not displacing, structural well-being strategies (Cohen et al., 2023; Knutsen Glette et al., 2023; Moy et al., 2021; St-Pierre et al., 2023).

Finally, the future value of passive sensing in the health care workforce will depend as much on governance as on sensor accuracy. Consent, privacy, transparency, data minimization, explicit limits on data use, and non-punitive implementation are not secondary concerns; they are prerequisites for trust. In that sense, the development of wearable sensing for health care worker well-being is not simply a technical challenge. It is simultaneously a clinical, organizational, ethical, and social challenge. Future research should therefore prioritize longer longitudinal cohorts, better adherence reporting, greater contextual integration, pragmatic intervention trials, and governance models that make digital monitoring acceptable, useful, and fair (Shen et al., 2022; Tindale et al., 2022; Tomičić et al., 2022).

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