

A Roadmap for Global Use of Wearable and Physiological Measures in Youth Mental Health Research

Harnessing wearable and physiological technologies to transform youth mental health research globally.

Executive Summary: A Roadmap for Global Youth Mental Health Measurement

This white paper presents a global roadmap for advancing **wearable and physiological measures** in youth mental health research, with a critical focus on **diverse and low-resource settings**. As digital health technologies become increasingly accessible, ensuring their deployment is **ethical, inclusive, and scientifically rigorous** is essential to transform discovery into care.

Wearable and smartphone-based tools enable the **continuous, real-world capture of behavior and physiology**, bridging the gap between laboratory precision and the lived experience of young people. However, the field is currently fragmented by proprietary systems, inconsistent data quality, and limited cross-regional harmonization. This roadmap outlines strategies to transform fragmentation into coordinated global progress through standardization, open infrastructure, and inclusive governance.

Core Principles

- **Inclusion:** Ensure broad participation and benefit across regions and populations in the development of youth mental health research and technologies.
- **Transparency:** Advance open science through shared standards, reproducible methods, and public accountability.
- **Sustainability:** Build local capacity and governance structures to ensure lasting impact beyond individual studies.

By bridging **laboratory precision with real-world relevance**, this roadmap establishes a foundation for transforming how youth mental health is **measured, understood, and supported globally**.

Key Priorities

For Researchers

- **Standardize Data Pipelines:** Adopt open, interoperable frameworks for data collection, multimodal integration, and artifact correction to improve reproducibility across regions.
- **Integrate Multi-Modal Data:** Combine wearables, smartphones, and **ecological momentary assessment (EMA)** for holistic, personalized insights.
- **Reduce Participant Burden:** Design protocols that minimize response fatigue and apply adaptive, AI-driven EMA methods to improve relevance and efficiency.
- **Ensure Cultural Calibration:** Verify that physiological and behavioral signals retain comparable meaning across diverse cultural and contextual settings.

For Funders

- **Invest in Local Leadership:** Empower LMIC researchers to lead regionally relevant, culturally grounded studies and sustain projects.
- **Support Affordable Devices:** Prioritize investment in the design, validation, and regional manufacturing of low-cost, discreet, research-grade devices tailored to low-resource settings.
- **Build Open Infrastructure:** Fund standardized APIs, open-source analysis tools, and shared, interoperable repositories to foster global collaboration.

For Policymakers

- **Protect Youth Data:** Enforce strong privacy and consent frameworks that adhere to local laws while maintaining global transparency standards.
- **Expand Digital Infrastructure:** Strengthen connectivity, power reliability, and cloud access in LMICs, prioritizing hubs such as schools and clinics as anchor points.
- **Advance Inclusive Governance:** Establish national guidelines for wearable data that are culturally appropriate and aligned with global standards.

For Industry Partners

- **Prioritize Research-Grade Features:** Ensure devices provide raw data access, minimize artifacts, and support customizable firmware.
- **Ensure Accessible Licensing:** Offer affordable or open access for LMIC researchers to prevent exclusionary pricing models.
- **Co-Develop with Communities:** Partner directly with local researchers, families, and youth to adapt designs that ensure cultural relevance, safety, and sustainability.

Introduction

The global youth mental health crisis demands measurement approaches that extend beyond brief, clinic-based assessments. Wearable and physiological technologies now offer scalable, real-time insights into behavior and biology that were previously unattainable. Yet their potential remains unevenly realized due to gaps in access, variability in data quality, and limited harmonization across diverse settings, underscoring the need for a global roadmap. The global ubiquity of mobile phones — with smartphone ownership exceeding ~70% of the world's population according to recent global analytics reports (Meltwater, 2025; GSMA Intelligence, 2024), as well as availability and scalability of low cost wearables and other mobile digital health and wellness technologies — provide a powerful platform for scalable mental health research.

In September 2024, the Stavros Niarchos Foundation Global Center for Child and Adolescent Mental Health at the Child Mind Institute convened an international gathering of experts to advance the harmonization of wearable and physiological measures in youth mental health research. Participants spanned academic, clinical, and technological sectors, with a particular focus on challenges in low- and middle-income countries (LMICs).

Discussions highlighted device-specific issues, data collection complexities, and the need for standardized protocols across regions with differing resources and cultural considerations. Access to wearable devices remains a critical barrier in many regions (Adepoju et al., 2024). Additional themes included wearable data quality, the role of AI in data representation, the needs of diverse populations, equipment costs, ease of use, and constraints common in LMICs, including cost, connectivity, infrastructure, and stigma.

This white paper synthesizes those discussions and offers a roadmap for researchers, funders, and policymakers to foster inclusive and effective use of wearable and other physiological measures worldwide. It also highlights how integration with laboratory-based methods can strengthen ecological validity and translational impact.

To ground these discussions, the following section outlines the scientific rationale for integrating wearable and laboratory-based methods and clarifies the key questions guiding this roadmap.

Scientific Rationale and Core Questions

Traditional in-clinic assessments provide valuable but limited snapshots of mental health. They are constrained by time, setting, and cost, and often fail to capture daily fluctuations in emotion, physiology, and behavior. These limitations are particularly acute in low- and middle-income countries (LMICs), where specialized clinical and laboratory infrastructure is scarce, travel to research sites can be prohibitive, and stigma around seeking care further restricts participation.

Wearable and smartphone-based tools offer a way to extend research and care into daily life — collecting **continuous, contextual, low-burden data** that would otherwise be impossible to capture at scale. For LMIC contexts, they represent not just convenience but **access and inclusion** — reducing cost and geographic barriers — while enabling participation of communities traditionally excluded from neuroscience and mental health research.

At the same time, the goal is not to replace laboratory science but to **connect it to real-world behavior**. Controlled, in-lab methods such as electroencephalography (EEG), virtual reality (VR), and mobile brain/body imaging (MoBI) provide mechanistic and validated benchmarks, while field-based wearables allow those same phenomena to be tracked under naturalistic conditions. Linking these domains creates a translational loop — where insights from the lab guide real-world measurement, and real-world data inform new experimental questions.

This roadmap addresses four interrelated aims that define this bridge:

- 1. Early Detection:** Identify deviations in sleep, activity, or autonomic regulation that may signal emerging mental health risk in longitudinal designs.
- 2. Improved Diagnostics:** Augment clinician-administered and laboratory tools with objective, ecologically grounded physiological indicators.
- 3. Treatment Monitoring:** Track response and adherence in real time to support adaptive care and precision interventions.
- 4. Scientific Discovery:** Generate multimodal, longitudinal datasets that connect neural, physiological, and behavioral dynamics across contexts and cultures.

By explicitly contrasting traditional, in-lab, and continuous real-world approaches, this roadmap positions wearable and physiological technologies as a bridge — enabling **scientific integration and equitable access** across settings.

Relationship to Existing Practice

Traditional mental health assessments have long relied on in-clinic evaluations, which provide indispensable, clinically validated insights for diagnosis and care. However, typical clinical encounters offer only **brief, structured, frequently clinic-specific snapshots** of functioning, lacking ecological and longitudinal correspondence with everyday life. These methods capture standardized measures of symptoms and performance but miss the rich daily variability and environmental context that shape youth mental health outside clinical settings. Within the broader research ecosystem, they remain essential as **baseline diagnostic anchors**, yet their reach and temporal resolution are inherently limited.

Novel in-clinic technologies, such as EEG, measuring event-related potentials (ERPs), and virtual reality (VR)-based paradigms, have expanded the scope of laboratory inquiry. They enable precise measurement of physiological and cognitive processes, offering **mechanistic validation** of underlying neural and behavioral systems. Yet these tools, while powerful, still face challenges in **generalizing findings to real-world contexts**, where experiences are less controlled and often more complex.

Out-of-clinic wearables bridge that gap by capturing **continuous, contextual data** — for example, patterns in sleep, physical activity, or autonomic regulation (e.g., heart rate variability). These signals provide early indicators of stress, risk, or resilience that evolve moment to moment. However, because such devices typically lack subjective input, they must often be paired with methods like ecological momentary assessment (EMA) to interpret meaning and context.

Finally, **smartphones** represent an additional, often underutilized opportunity for “opportunistic” data collection. Passive indicators such as mobility, screen use, communication frequency, or even voice tone can reflect behavioral and emotional states. Their ubiquity makes them a powerful, **low-cost and scalable** research tool, particularly in LMIC settings where specialized devices may be inaccessible. Yet the same accessibility introduces ethical considerations — particularly regarding **privacy, consent, and interpretation without clear clinical guardrails**.

Taken together, these complementary approaches outline a continuum from controlled laboratory settings to naturalistic daily life. The goal is not to replace any one method but to **connect them** — linking mechanistic understanding from lab studies to the ecological precision and inclusivity enabled by digital, real-world assessment tools.

For clarity, wearables refer to wrist-, finger-, or clip-based devices that passively collect signals such as activity, heart rate, or temperature, while physiological measures encompass both wearable and laboratory-based technologies, including EEG, VR, ERP, HR/HRV, temperature, movement, and voice recordings. These tools collectively enable the continuous, multimodal assessment of behavior and biology across diverse contexts.

Challenges in Data Collection

The Cost of Fragmentation

Today’s wearable and app ecosystem is highly fragmented — hundreds of devices, proprietary algorithms, and closed data formats prevent replication and cross-study comparison. Without coordinated standards and open infrastructure, the field risks producing islands of data that cannot be synthesized. Establishing shared validation protocols, common

data models, and interoperable repositories is therefore not optional; it is the precondition for progress.

Fragmentation affects every stage of the research pipeline: from device calibration and signal processing to data analysis, annotation, and sharing. This challenge is particularly acute in LMIC contexts, where limited access to commercial research platforms and proprietary software compounds inequities in data participation. Without open tools and shared infrastructure, even well-conducted local studies risk becoming isolated silos, limiting their contribution to global scientific understanding.

Addressing fragmentation is not only about comparability — it represents the pathway from calibration to comparability to individualization. Standardization facilitates clinical/patient adaptation and creates the foundation for robust cross-study comparisons, while harmonized data pipelines enable the detection of individual-level patterns and trajectories, advancing the field toward true **precision mental health**.

Device-Specific Challenges and Solutions

Challenges inherent to the devices themselves pose significant hurdles to effective data collection. A primary concern is ensuring the comfort and proper fit of wearable devices, especially for youth, as accurate data depends on consistent and correct placement (Cho et al., 2021). Globally, device wear is often intermittent, and usage patterns are shaped by cultural norms, resource constraints, and perceptions of stigma — factors that can lead to unreliable or incomplete data. For example, in some communities, wrist-worn devices may be viewed as jewelry and considered inappropriate for boys, while in others, visible sensors may carry associations with illness or disability. Recent policy developments in Brazil further underscore the dynamic social context in which wearable data collection occurs: following the rapid approval of a federal law banning cell phones in schools, many institutions have extended these restrictions to include all screen-based devices, effectively prohibiting wearables with digital displays on campus. Such policy shifts highlight how quickly local norms can evolve, reinforcing the need for adaptable research protocols and culturally responsive device design.

In addition, socioeconomic conditions can strongly influence whether devices are worn consistently. In settings of poverty, parents may be reluctant to let children wear visible devices out of rightful concern for theft, unwanted attention, or safety, making adherence especially difficult (Cho et al., 2021; Pandey et al., 2025).

Recommendations:

- **Device Selection and Customization:** Support collective initiatives (e.g., consortia, funder-led programs, or regional partnerships) that work with manufacturers to adapt devices for discreet use, local language interfaces, and culturally sensitive designs. Prioritize clip-on or

minimally visible wearables to reduce stigma, improve comfort, and increase safety.

- **Pilot Projects for Low-Cost Device Validation:** Fund affordable, validated device options tailored to low-resource settings, in collaboration with national health systems, regulatory agencies, and regional organizations. Support the development of a shared catalog of validated devices and promote international standards for validation and interoperability. Reduce costs by engaging regional manufacturers and technology partners to minimize import taxes and shipping costs.

Standardization Across Regions

Variability in research protocols poses a significant challenge to the generalizability of findings, particularly in diverse and low-resource settings. For example, one study may ask participants to wear an activity tracker continuously for two weeks, while another uses the same device only during nighttime sleep. Similarly, ecological momentary assessment (EMA) protocols can differ widely with respect to both content (e.g., the specific constructs and prompts used) and sampling strategies (e.g., some integrate wearable data with multiple daily prompts, while others rely on once-daily reports). These differences make it difficult to compare or pool findings across studies.

Beyond procedural variability, ensuring measurement invariance across cultural and contextual settings is equally essential. Though most often discussed in relation to questionnaires and surveys, physiological and behavioral signals can also have distinct normative baselines and contextual meanings across populations — for instance, resting heart rate, physical activity, or sleep duration may vary systematically by climate, occupation, or social norms. Efforts to standardize data collection and processing must therefore extend beyond technical alignment to include cultural calibration — verifying that the same physiological signal reflects comparable psychological constructs across contexts.

Rigorous training of local researchers on device setup, troubleshooting, data analysis, and interpretation not only improves data quality but also builds sustainable local capacity. Adaptable validation protocols are also needed in LMICs, where intermittent data collection may be unavoidable. Local safety concerns, such as the risk of theft or stigma associated with wearing devices, should be addressed through discreet design and community consultation. Targeted efforts to work with local mental health professionals, educators, community leaders, and adolescents with lived experience can foster more positive perceptions of mental health research and wearable technologies. Finally, desensitization protocols are vital for pediatric populations to help young participants acclimate to wearing caps, cables, glasses, or recording devices (e.g., EEG), ensuring successful data acquisition and cooperation.

Global Governance and Field Principles

Beyond technical and regional challenges, the field requires robust global governance frameworks to ensure that youth mental health research using wearable and physiological measures is fair, sustainable, and ethically sound.

Recommendations:

- **Global Standards Board:** Establish a standing board comprising international researchers, including LMIC representation, alongside neuroethicists and community representatives with lived experience.
- **Flexible Standards:** Develop modular, descriptive protocols adaptable to local resources, rather than prescriptive one-size-fits-all guidelines.
- **Partnerships with Local Researchers:** Fund projects that empower local researchers to lead studies, ensuring that protocols are culturally sensitive, regionally relevant, and sustainable.
- **Ethical Industry Collaboration:** Work with commercial partners through transparent, ethically grounded agreements that prioritize data privacy and accessibility.
- **Data Privacy as a Core Principle:** Adopt and enforce comprehensive data privacy and ethics protocols across all studies, adhering strictly to local laws while maintaining global standards of transparency.

Data Understanding and Representation

Data Privacy and Ethics

Rigorous data privacy and ethics protocols are essential for building trust and ensuring the responsible use of physiological data. Key concerns include safeguarding identifiable information, addressing participants' privacy expectations, and ensuring compliance with local regulations. Transparent practices and clear communication with families and youth are central to promoting responsible data use.

Recommendations

- **Comprehensive Protocols:** Establish and enforce robust data privacy and ethics frameworks.
- **Open Platforms:** Maintain de-identified data sharing through open repositories to prevent siloing and encourage harmonization to facilitate discovery.
- **Capacity Building:** Train local research teams in privacy regulations and best practices.
- **Participant Education:** Provide clear training and communication to youth and families to maximize device use while protecting privacy.

Annotation Frameworks and Standards

A persistent challenge is the lack of standardized annotation frameworks. Reliable annotation requires clear ontologies that define what should be labeled and how, supported by open-source platforms to ensure transparency and reproducibility. While AI can assist in filtering large datasets, fully automated annotation is unlikely to be sufficient; human expertise and consensus-driven standards remain essential to ensure accuracy and cultural validity.

Recommendations

- **Open-Source Ontologies:** Develop and adopt ontology-based annotation frameworks.
- **Consensus Building:** Build agreement across research teams on what should be annotated and how.
- **Hybrid Approaches:** Combine AI-assisted annotation with expert human review.

Extracting Meaningful Information with AI

The large volume of data generated by wearables and laboratory-based measures cannot be analyzed effectively without AI-enabled methods. Approaches such as machine learning and deep learning can help separate meaningful signal from irrelevant noise, provided they remain transparent, reproducible, and interpretable. Beyond filtering noise, these methods can generate richer descriptions of complex patterns, offering new insights into youth mental health when applied responsibly.

Recommendations

- **Interpretable Methods:** Apply AI approaches that remain transparent and reproducible.
- **Data Curation:** Use AI to identify relevant segments from long recordings.
- **Adaptive Frameworks:** Develop AI-powered taxonomies that refine schemas based on regional and cultural differences.

Real-World Applications and Integration

Real-Time Compliance Monitoring and Passive Sensing

Consistent device usage is essential for data quality. Real-time compliance monitoring, such as tracking heart rate (HR) or heart rate variability (HRV), can help identify and address non-compliance. HR is widely available on most consumer devices, while HRV provides a more sensitive marker of stress, arousal, and adherence, though its accuracy depends on device quality. Compensation to participants may

improve compliance but must be managed carefully to avoid perceptions of coercion. Wearable devices that collect data passively are less burdensome, making them ideal for research in naturalistic settings.

Recommendations

- **Invest in Passive Sensing:** Funders should prioritize devices that enable passive data collection to enhance compliance, especially in LMICs.
- **HR/HRV Indicators:** Use HR for broad compliance monitoring, and HRV where device quality permits, recognizing the limitations of consumer-grade devices.

Opportunistic Passive Data Collection

In addition to purpose-built wearables, smartphones and other personal devices offer opportunities for “opportunistic” data collection. Passive digital phenotyping can capture mobility (via GPS), communication and social patterns (texts, calls, app use), screen time, typing behavior, and even vocal features from everyday phone use. These signals provide valuable context to complement wearable and EMA data, expanding reach in regions where smartphones are more accessible than research-grade devices.

At the same time, accessing opportunistic data introduces significant ethical challenges, including heightened privacy concerns, risks of surveillance, and the need for transparent, youth-centered consent processes. Integration of such data streams must balance their scientific value with robust governance frameworks that protect participant autonomy and ensure community trust.

Recommendations:

- **Smartphone as Sensor:** Leverage widely available smartphones as low-cost passive sensors, particularly in LMIC contexts.
- **Contextual Integration:** Combine opportunistic streams (mobility, screen time, voice) with wearable and EMA data to enrich ecological validity.
- **Ethical Safeguards:** Develop transparent consent processes, strict data minimization protocols, and oversight mechanisms to prevent misuse.
- **Standardized APIs:** Promote open, standardized methods for extracting smartphone data to ensure comparability across studies.

Multi-Modal Integration and Ecological Momentary Assessments (EMA)

Integrating wearable data with ecological momentary assessments (EMA) provides a richer understanding of real-world behavior and psychological states, enhancing ecological validity and clinical relevance. EMA allows researchers to capture mental states in the moment, contextualizing

physiological signals with subjective experience. Combined with passive wearable sensing, these methods help identify triggers, monitor fluctuations, and tailor interventions.

Building on foundational work such as the NIMH-supported MMARCH consortium (Merikangas et al.), which demonstrated the feasibility and value of EMA in capturing daily fluctuations in mood and behavior, future studies should integrate these approaches with wearable technologies to generate richer, multi-modal datasets. Despite their promise, EMA protocols face challenges including participant burden, variability in design, and integration complexity across modalities. Standardizing approaches and leveraging adaptive technologies are critical to realizing their full potential.

Recommendations:

- **Multi-Modal Data Collection:** Fund studies that combine wearable, self-reported, and contextual data to provide comprehensive insight into youth mental health.
- **Personalized Insights:** Use combined data sources to generate individualized profiles of mental health dynamics.
- **Reduce Participant Burden:** Design EMA protocols that minimize response fatigue and intrusiveness while preserving data quality.
- **Standardize EMA Protocols:** Promote harmonization of EMA frequency, timing, and integration with wearable data across research teams.
- **Adaptive EMA Approaches:** Apply AI to deliver context-sensitive EMA prompts triggered by physiological or behavioral signals, improving relevance and efficiency.

Advancing Sustainable EMA Engagement

Sustained engagement with ecological momentary assessment (EMA) protocols remains a critical challenge, particularly in real-world and low-resource settings where financial incentives may be impractical or unavailable. Most existing studies rely on monetary rewards to drive compliance, raising questions about the ecological validity of adherence rates. Future research must explore alternative incentive models that are scalable, sustainable, and culturally appropriate. Lessons from game design and digital behavior science can be leveraged — for example, by integrating achievement badges, progress indicators, or reputation-based systems within EMA platforms to reinforce participation. Collaborations with behavioral scientists, youth participants, **and game designers** may help identify incentive frameworks that are both ethically sound and effective across diverse cultural and socioeconomic contexts.

Bridging the Lab and Real-World

Bridging laboratory and real-world research is essential to achieving both scientific rigor and global relevance. Laboratory methods enable mechanistic insight and controlled validation, while real-world approaches, such as wearables and mobile platforms, capture the contextual variability that shapes youth mental health. In LMIC settings, where access to traditional research infrastructure may be limited, this integration provides an equitable pathway for high-quality, ecologically valid data collection. Together, these approaches form the backbone of a translational framework that links precision measurement with real-world application.

Integrated Designs and Immersive Technologies

Wearables provide scalability, while laboratory methods enable validation and mechanistic insight. This integration strengthens translational relevance and ensures findings remain ecologically meaningful.

Recommendations:

- **Integrated Designs:** Combine lab and field studies to maximize both rigor and ecological validity.
- **VR and Immersive Tech:** Use VR and similar platforms to simulate real-world conditions in lab settings, improving generalizability.

Electroencephalography (EEG) and Event-Related Potentials (ERPs)

Electroencephalography (EEG) and derived event-related potentials (ERPs) remain powerful tools for understanding cognitive and affective processes. Emerging wearable EEG formats are beginning to expand their use beyond labs, offering new opportunities for naturalistic applications. Protocol variability remains a challenge: standard clinical paradigms have limited utility, steady-state responses offer promise for standardization, while cognitive ERPs remain heterogeneous (Mushtaq et al., 2024). AI-assisted preprocessing may improve reproducibility, but consensus protocols are needed.

Recommendations:

- **Standardized ERP Paradigms:** Develop consensus on ERP measures with clear clinical utility, prioritizing steady-state designs.
- **Wearable EEG Integration:** Explore wearable EEG as a complementary method, addressing issues of stigma, comfort, and data quality.
- **AI Preprocessing Pipelines:** Apply AI-supported preprocessing and validation pipelines to improve reproducibility across sites.

Mobile Brain/Body Imaging (MoBI)

Mobile Brain/Body Imaging (MoBI) represents a next-generation approach to bridging laboratory and real-world research (Makeig et al., 2009; Gramman et al., 2014). By synchronizing EEG, motion capture, eye-tracking, and other physiological measures, MoBI enables the study of cognition and behavior in naturalistic settings while preserving mechanistic insight. This approach directly addresses the limitations of traditional lab-only paradigms, expanding the ability to study attention, emotion, and executive functioning during real-world tasks.

Global research teams, including investments led by CMI (https://childmindresearch.github.io/MoBI_Docs/) and its partners (e.g., Ojeda et al., 2014), have advanced MoBI infrastructure and open-science tools such as standardized acquisition protocols, preprocessing pipelines, and international training efforts. These efforts position MoBI as a critical component of the roadmap for integrating laboratory-based and ecological measures in youth mental health research.

Recommendations:

- **MoBI Standardization:** Develop shared protocols and pipelines to harmonize MoBI datasets across sites, building on existing CMI-led open frameworks.
- **Training and Dissemination:** Expand training programs and capacity-building efforts to ensure MoBI methods are accessible to LMIC researchers as well as high-resource sites.
- **Global Collaborations:** Leverage CMI's leadership in MoBI consortia to advance international projects, ensuring broad access to data and tools.
- **Ecological Applications:** Prioritize MoBI for tasks that simulate real-world cognitive and affective demands, enhancing translational impact.

Artifact Handling

Artifacts are a pervasive challenge across wearable and laboratory-based measures, arising from both physiological and environmental sources. In EEG and MoBI, movement and systemic artifacts can obscure neural signals; in accelerometry and HR/HRV data, noise from inconsistent wear, device drift, or connectivity gaps often undermines reliability. In low-resource settings, additional challenges such as intermittent internet access and power outages can further impact artifact-free data collection.

Robust pipelines and statistical strategies for detecting, correcting, or modeling these artifacts are essential to ensure comparability across studies and sites. Equally important are innovations in device design and real-time monitoring to minimize artifacts at the point of collection.

Recommendations:

- **Standardize Pipelines:** Develop and share robust preprocessing pipelines for artifact detection and correction across modalities.
- **Advance Hardware Solutions:** Encourage device manufacturers to design sensors and firmware that reduce artifact susceptibility at the source.
- **Address Missingness:** Promote statistical approaches for handling missing or corrupted data that preserve analytic validity and comparability.
- **Build Transparency:** Require that studies report artifact-handling methods explicitly to improve reproducibility and trust in findings.

The translational value of these methods ultimately depends on how effectively they are integrated into everyday clinical workflows — a theme expanded in the next section.

Future Directions

The next phase of wearable and physiological research must advance on two parallel fronts: governance and innovation. Wearable and physiological data have the potential to transform not only research but also clinical care. To realize this, findings must be translated into clinical workflows, enabling earlier detection, objective diagnostics, and dynamic treatment monitoring. Integration with health-system infrastructures, whether through hospital records, community programs, or school-based initiatives, will be key. This process will also require establishing the clinical significance of digital biomarkers and ensuring regulatory alignment. The long-term vision is a continuum from discovery to deployment, where validated metrics guide personalized, just-in-time adaptive interventions (JITAs) — digital or behavioral supports triggered automatically by changes in physiological or behavioral signals such as elevated stress levels, disrupted sleep, or deviations from normal activity patterns — and inform everyday clinical decision-making.

Pathways to Clinical Integration

Translating wearable and physiological data into practice requires context-sensitive pathways that link research, technology, and care delivery. In high-resource settings, integration may occur through electronic health records (EHRs) and clinician dashboards, creating continuous feedback loops between objective data and treatment decisions. In many low- and middle-income countries (LMICs), however, EHR infrastructure remains limited or fragmented. Here, integration may instead take place through school-based health programs, community clinics, or mobile-health (mHealth) platforms that can serve as digital conduits for data sharing, follow-up, and real-time feedback.

Training modules for clinicians, youth, and families — mirroring the adoption of actigraphy in sleep medicine — can promote digital literacy, trust, and sustained engagement. Across all contexts, the emphasis should remain on complementarity: digital tools are meant to extend, not replace, human judgment. Pilot implementations co-developed with local health systems and educational partners can demonstrate practical workflows, sustainable reimbursement models, and regionally relevant pathways to adoption.

Ultimately, these implementation efforts must rest on strong governance frameworks that ensure ethical data use, equitable access, and scientific transparency.

Inclusive Governance

Collaborations with commercial entities can expand data availability and scalability, but only if built on principles of fair access, transparency, and accountability. Agreements must guarantee access to raw, research-grade data (rather than proprietary summary metrics), fair and transparent intellectual property (IP) arrangements, and strict protections for youth data. Partnerships should involve local actors as well as global firms, ensuring that technologies are adapted to community needs and not imposed in extractive ways. Safeguards against exploitative licensing models or youth data monetization are essential, particularly in LMIC contexts.

Scientific Innovation

Future research should prioritize:

- **Multimodal integration:** Linking wearables with ecological momentary assessments (EMA), Mobile Brain/Body Imaging (MoBI), voice and speech markers, and even genomics to capture both dynamic state changes and stable biological traits.
- **Adaptive, real-time interventions:** For example, EMA prompts could be triggered by daytime spikes in HRV or by patterns observed following sleep disruption (without interrupting rest); VR or AR simulations might scaffold coping strategies during lab sessions and then extend them into daily life; or real-time digital phenotyping could be linked to just-in-time adaptive interventions (JITAs).
- **Global longitudinal datasets:** Building multi-region cohorts that combine wearable, behavioral, and biological data collected over years, modeled after initiatives like the Healthy Brain Network but explicitly incorporating LMIC leadership. These datasets would allow for developmental mapping of youth mental health across cultural and socioeconomic contexts, filling one of the largest current gaps.

Capacity Building

None of this progress will be sustainable without significant investment in training and infrastructure. LMIC researchers and local teams must be resourced to lead projects, adapt protocols, and sustain regionally relevant innovations. Training programs should cover device setup, troubleshooting, multimodal data integration, AI-supported analysis, and governance frameworks, ensuring broad participation in the global research ecosystem.

Recommendations:

- **Ethical partnerships:** Develop and share robust preprocessing pipelines fEstablish agreements that guarantee raw data access, fair and transparent IP, and robust youth data protections, while preventing exploitative licensing or data monetization.
- **Global datasets:** Invest in large-scale, longitudinal, multimodal cohorts that track youth development across diverse contexts, with LMIC researchers in leadership roles.
- **Capacity building and training:** Expand infrastructure support and technical training programs that equip local teams to lead studies and sustain regionally relevant projects.
- **Innovation focus:** Fund multimodal integration (e.g., wearables + EMA + MoBI), and support the development of adaptive, real-time interventions that translate into both clinical and community settings.

Key Actionable Recommendations

For Funders

- **Ethical partnerships:** Prioritize investment in the design, validation, and regional manufacturing of low-cost, research-grade devices tailored to LMIC needs. This should include discreet designs (e.g., clip-ons), local language interfaces, and strategies to reduce import costs.
- **Establish Global Collaboration Networks:** Fund consortia that connect LMIC researchers with international experts, modeled after the Global Brain Consortium or Healthy Brain Network. These networks should harmonize protocols, create shared validation catalogs, and build interoperable repositories.
- **Coordinate Funder Collaboration:** Create mechanisms for multiple funders to pool resources, reducing duplication and extending reach across regions. For example, shared infrastructure grants or pooled device-purchasing agreements could support multiple LMIC sites simultaneously.

For Researchers

- **Define a Core Dataset:** Build consensus around a minimum core dataset (e.g., HR/HRV, sleep, activity, EMA frequency), ensuring comparability across studies while allowing regional adaptation.
- **Develop Open-Source Tools and Protocols:** Release modular, open-source pipelines for data extraction, multimodal integration (wearables, EMA, MoBI), and artifact correction. Provide accompanying training materials to build adoption.
- **Leverage AI Responsibly:** Apply interpretable AI pipelines for noise reduction and adaptive taxonomies. Benchmark models against open datasets to ensure transparency, reproducibility, and cultural relevance.
- **Advance Open Science:** Commit to preregistration, transparent reporting of artifact handling, and open release of de-identified data to maximize reproducibility and impact.

For Policymakers

- **Promote Open Access and Ethical Standards:** Enforce policies requiring youth data protections, clear consent protocols, and public availability of de-identified findings. Support open repositories at national or regional levels.
- **Invest in Digital Infrastructure:** Expand internet connectivity, electricity reliability, and cloud access in LMICs to enable continuous data collection. Prioritize hubs (e.g., schools, clinics) as anchor points for infrastructure upgrades.
- **Support Inclusive Governance:** Partner with researchers and communities to establish national guidelines for wearable and physiological data that are culturally appropriate and aligned with global standards. Policies should also address social barriers to adoption. Gender norms and national restrictions on visible or screen-based devices highlight the need for discreet, culturally sensitive designs and active community engagement during implementation.

For Industry Partners

- **Prioritize Research-Grade Features:** Build devices that provide access to raw data streams, minimize artifact susceptibility, and include customizable firmware for research needs.
- **Ensure Accessible Licensing:** Structure agreements to allow LMIC researchers affordable or open access to devices and software, preventing exclusionary pricing models.
- **Co-Develop with Communities:** Work directly with local researchers, families, and youth to adapt designs, ensuring wearables are culturally acceptable, safe, and sustainable.

Conclusion

This white paper lays out a clear roadmap for harnessing wearable and physiological measures to transform youth mental health research. By fostering international partnerships, standardizing protocols, and addressing the unique needs of diverse populations, the global research community can create effective, data-driven interventions for young people worldwide. The true power of these tools lies not just in the data they provide, but in their potential to bridge the gap between rigorous lab-based research and the complexities of real-world behavior.

Our collective task is to ensure that this burgeoning field is built on a foundation of fairness, transparency, and collaboration, allowing us to move beyond fragmented studies toward a unified global effort. The ambitious vision outlined in this white paper, however, hinges on the collective and sustained commitment of diverse stakeholders to overcome significant institutional and financial barriers. Achieving this will require targeted investment in locally led initiatives, open-source tools, and adaptive AI methods that are accessible to all. Funders must commit to affordable, regionally relevant technologies; researchers must advance open standards and reproducible methods; policymakers must safeguard ethical data use and broaden access; and industry partners must prioritize transparency and youth protection. Only through these aligned efforts can we ensure that findings are not only representative and ethical, but also scalable and clinically impactful for every young person, regardless of their circumstances.

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