Wearable Technology and Daily Diaries for Studying Mental Health: Lessons Learned from Pilot Studies in Kampala, Uganda

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Abstract

Wearable technology and daily diaries offer insights into everyday behaviors that can further health research and treatment globally. However, use of these methodologies outside of high-income settings has been limited. We conducted two pilot studies that enrolled 60 young women in the urban slums of Kampala, Uganda to understand design considerations associated with using wearable technology and daily diaries in this context. Each participant in the pilot studies

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was asked to wear a wearable activity tracker and complete daily diary questionnaires for five days. Based on our experiences, we identified several lessons that may be beneficial to others interested in implementing wearable technology and daily self-reports in their research and interventions, particularly when working in low-resource contexts. We discuss the importance of designing solutions tailored to the available resources, building in validation for the most critical measures, investing in data management efforts, and providing transparent and culturally accessible information to participants. Examples from our study are provided. These lessons may reduce the barriers and improve data quality for future researchers and practitioners interested in using these data collection methods globally.

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Impact Statement

Wearable technology provides opportunities for passive data collection related to correlates of mental health including sleep and physical activity. Additionally, daily diaries can be used to validate and supplement wearable data on sleep and physical activity. Much of the extant work using wearable technology has focused on applications in high-income settings. However, low-resource settings can benefit from similar data collection strategies. Our lessons learned highlight the need to design the study approach factoring in available resources, to build in a system of validation for the most critical measures, to invest in data management efforts, and to provide complete, transparent and culturally accessible information to participants. Beyond our pilot and planned full cohort studies in the slums of Kampala, Uganda, these lessons also provide broader insights into conducting mental health research in sub-Saharan Africa and highlight participant experiences that may be generalizable to similar settings. Sharing these experiences can lower the barrier to conducting behavioral research using wearable technology and daily diaries in low-resource settings, where such research is urgently needed but capacity remains limited.

Key words

Mobile health, actigraphy, developing countries, cultural sensitivity, global mental health

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Introduction

Variation in everyday behaviors, including sleep, can provide important insights into individuals' mental health. Several methodologies are available for collecting detailed information concerning everyday activities, including daily diaries and wearable devices (Del Din et al. 2020; Schokman et al. 2018). Such methodologies can be implemented at relatively low cost with little participant burden. However, wearables and accompanying daily diaries for data collection are not yet widespread - wearables are only beginning to gain traction in low- and middle-income countries (LMICs).

Daily diaries offer detailed insights into day-to-day variability in health behaviors with high ecological validity. Daily diaries are questionnaires that are administered to participants once per day over a defined duration, in writing, in person, over the phone, or through another medium (Lischetzke 2014). Daily diaries have been successfully implemented in LMICs and low-resource settings (Kiene et al. 2016; Sileo et al. 2016). In addition to standalone use, daily diaries can supplement and validate data from other sources including wearable technology.

Wearable technology can likewise be used alone or paired with daily diaries. Consumer wearables, such as wearable fitness trackers, have been popularized as an affordable, unobtrusive way to collect detailed longitudinal data from participants (Lauderdale et al. 2008). Data that can be passively collected with wearables, such as activity and sleep, would otherwise be subject to individual interpretation of questions, data entry errors, and other omissions when using surveys (Haghayegh et al. 2019; Schokman et al. 2018). Existing work in the United States discusses lessons learned for researchers interested in using wearables, including the importance of piloting, data monitoring, and trust and engagement from the participant (L'Hommedieu et al. 2019).

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Several recent studies have used wearables in clinical settings in LMICs, where wearables can provide a low-cost option for monitoring vital signs (Garbern et al. 2019; Ghomrawi et al. 2023; Van et al. 2021). Recent research has introduced wearables for behavioral studies of healthy individuals in LMICs, including feasibility studies in rural Burkina Faso (Huhn et al. 2022b) and Cambodia (Liverani et al. 2021). Both studies found the devices feasible and acceptable, with noted challenges such as battery life, technical issues, and the influence of social desirability on self-reported acceptability measures. Wearables have also been used by researchers in Tanzania for tracking physical activity in older adults (Del Din et al. 2020) and in Sri Lanka to measure sleep (Schokman et al. 2018).

Despite these studies, there remains low utilization of wearable technology for research in LMICs. A scoping review of mobile health interventions for maternal and child health in LMICs found that only 5% of identified studies utilized wearable devices in sub-Saharan Africa (Huhn et al. 2022a). A barrier to uptake of this technology is the limited available guidance for researchers and practitioners implementing wearable devices in LMICs. One notable publication in this area outlines lessons learned for the logistics of data collection using wearables in Kenya (Johnson et al. 2023). The authors provide valuable tips including the need to plan for international procurement, select technology that has been proven in a research context, and provide local support to participants with a dedicated team member for wearables and information sheets for participants.

Our research implementing wearables and daily diaries with young women living in the slums of Kampala, Uganda extends the insights provided by Johnson et al (2023) while considering key differences between our study populations. Drawing from our pilot study, we

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offer four additional lessons learned, highlighting the importance of tailoring approaches to the unique lived experiences of participants.

Study Summary

The Onward Project on Well-being and Adversity (TOPOWA, meaning "to not give up") is an observational, mixed-methods prospective cohort study of 300 adolescent girls and young women, ages 18 – 24 years, living in the urban slums of Kampala, Uganda. Prior studies in these communities have identified limited economic opportunities (Kamara et al. 2019) as a source of stress, with the majority of girls aged 12 – 18 self-reporting depression and anxiety, over a third engaging in substance use (Perry et al. 2024), and more than 20% engaging in sex work (Swahn et al. 2016). TOPOWA was designed to understand how a Socio-economic Strengthening Targeted Training (SeSTT) program implemented by Uganda Youth Development Link (UYDEL), a non-governmental organization, impacts social stressors and mental health. UYDEL staff recruited participants living within 2000 meters of one of three UYDEL drop-in centers (Banda, Bwaise, or Makindye) in July and August, 2023. The study design included half of participants undergoing a 3-month SeSTT program administered by UYDEL, and all participants receiving surveys and wearing fitness trackers continuously for 5-day measurement bursts at the start of the study and at regular intervals for over two years. Surveys include measures to quantify anxiety, depression, and PTSD symptoms, as well as substance use, financial stress, quality of life, and other factors that can affect mental health. This study builds on over a decade of collaborative mental health research (Culbreth et al. 2018, 2021; Perry et al. 2024; Swahn et al. 2014). The project team includes Ugandan and American researchers, a youth advisory board of Kampala residents, and an advisory board of senior researchers and government

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representatives – all of whom have helped to shape the study throughout its conception and implementation.

Two pilot studies were launched prior to the larger study to examine the feasibility, acceptability, and best practices for wearable devices (Garmin vívoactive 3 smartwatches, discussed below), daily diaries, and selected survey questions (Culbreth et al. 2024; Nielsen et al. 2024; Swahn et al. 2024). Participants did not receive SeSTT. The protocol is described in Supplement 1. Written informed consent was obtained from all 60 participants, and institutional review boards at the Uganda National Council for Science and Technology and Makerere University approved the pilot studies. Participants were given wearables for continuous use across 5 days and nights to measure steps, sleep, and location (second pilot only). Participants were asked to return both the wearable and the daily diary booklet after five days.

Lessons learned

Design the study with the available technology

Collecting data in low-resource contexts can present a variety of challenges, particularly when using technology developed primarily for use in high-resource settings with readily available electricity and smartphone access. We made several decisions when designing our study that were driven by anticipated infrastructure constraints and previous experiences working in this setting. Limited access to electricity and internet, lack of mobile phone ownership (Swahn et al. 2014), and limited familiarity with smartphones and fitness trackers were potential constraints facing our study population.

To avoid these constraints, and because our selected devices could collect data for five days without recharging, we elected to use a measurement burst design for collecting data from

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wearables within the full study (Sliwinski 2008). This design allowed the research team time to recharge devices and offload data. Given our interest in immediate and delayed impacts of SeSTT, we selected three five-day periods for data collection with wearables: prior to the SeSTT program, immediately following program completion, and several months after program completion. Our pilot study was limited to a single five-day period.

Our chosen device needed to work within the identified study constraints and design. As Johnson and colleagues note (2023), reviewing prior research helps researchers and practitioners avoid devices that will not meet data quality or availability needs. A few major brands of wearables are most commonly used for research (Henriksen et al. 2018). We chose to use Garmin vívoactive 3 smartwatches. These devices were able to collect the desired activity, sleep, and location data. They did not need to connect to a smartphone in order to collect and store data, and had settings that allowed for battery life of up to 5 days. Cost also factored into our device selection. The Garmin vívoactive 3 smartwatches were available refurbished and more affordable than other devices that met our data collection, storage, and battery life requirements.

We also considered technology availability when designing the daily diaries. Rather than using online or app-based surveys, we printed booklets for participants to take home and complete each day. This required planning to finalize questions, print booklets, and account for additional data entry, but ultimately was an accessible option for all participants.

Build in validation for crucial information

Implementations in low-resource settings can result in unique hurdles for ensuring that key study measures are collected as completely and accurately as possible. Our motivation for including both a wearable device and daily diary was to ensure that key study information was collected and validated (Alinia et al. 2021; Brakenhoff et al. 2021; Menghini et al. 2023). While

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neither data collection method was perfect, the combination was chosen to provide adequate overlap to more reliably capture desired behavioral measures.

Several decisions are necessary when including validation or redundancies. First, the study team must decide if the repeated measurement is truly necessary, and if it undermines plans for minimizing participant burden. Asking participants to report on behavior collected by the wearables adds burden to the participant but may be needed to triangulate important learnings, especially if recall bias or other social desirability bias may contribute to inaccurate self-reporting. A second set of decisions involves reconciling inconsistencies and determining how to construct final measures for analysis when redundant data is collected. Prior to study start, the team should determine which measures will be the primary source of information, which measures will be used to fill in missing values or to validate the primary information sources, and whether inconsistencies are a meaningful measure that will additionally be analyzed and reported. Internal and pilot testing can help identify decision points.

These strategies were necessary for our measurement of sleep duration, which was identified during study development as an important measure for understanding mental health. Collecting sleep duration using wearables in our research setting had advantages (objective, not subject to recall) and disadvantages (data not collected if the device is removed or ill-fitting, or if the battery dies). Therefore, we elected to collect sleep-related measures from both the wearable and daily diaries. We chose to use wearable-recorded sleep times when available and self-reported daily diary sleep times otherwise.

The validation process should also include detailed data summaries and exploratory plots to identify unusual observations or patterns in the data that indicate data loss, data entry errors, and related issues. We implemented data quality checks to identify unusual day-to-day

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variability and differences between the two data modalities on a single day for additional inspection. In one instance during our pilot studies, the study team discovered that a participant had no recorded steps on a given day, but also had multiple location recordings, indicating that she had walked to at least one location that day. This led to the discovery of mismatched devices and accounts, which was subsequently resolved by referencing daily diaries.

Invest in data management and backups

Data management is universally important in research and public health practice but has unique challenges at the intersection of the large quantities of data from wearable technology, linking multiple data sources, and international collaboration. Careful documentation is needed to ensure that data from multiple modalities can be linked. Protocols for data backups are necessary to ensure that data are not lost due to infrastructure challenges and are securely shared with collaborators. Moreover, because devices can fail after repeated use, all devices should be tested regularly to avoid data loss.

We took several steps to ensure successful data linkage. Devices had multiple unique identifiers, including a physical engraved identifier, an identifier internal to the device, and a second internal identifier that displayed when syncing. Prior to starting data collection, we created accounts that were unique to each device based on the engraved identifier. Careful documentation of all identifiers and pairings of participants to devices was maintained to ensure that all data could be correctly linked to participants.

Reliability of computing resources, internet access, and electricity, for both participants and the research team, is an additional consideration that can influence decisions around data storage. We chose to use paper daily diary booklets and procured computers with faster processing speed for the research team following data upload delays during the pilot. For

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researchers interested in using digital daily diaries, the selected technology should be robust to unstable electricity, internet outages, and device limitations to avoid potential data loss. Offline data collection and backups with flexibility for uploading may be preferred.

We recommend maintaining a separate, unmodified copy of all data from each wearable device each time it is returned. This can help avoid data loss when using syncing services intended for consumer wearables. For example, incongruent step counts and travel behavior in synced data described in the previous section occurred during pilot testing, prior to our decision to store separate file backups. We were able to partially recover and correctly match data given our identifier documentation. With complete file backups, we are now able to completely resolve similar issues with no data loss.

The technical training of local team members is also critical. Developing procedures and protocols for study team members on data documentation and backups is key for success. Our study team members were responsible for clarifying survey and daily diary responses upon completion. They also transcribed responses into electronic databases, introducing the potential for human error. Recognizing the importance of accurate transcription and keeping original copies of data collection instruments can improve data products.

Provide transparent and culturally accessible information to participants

Understanding participants' technology literacy is critical to informing protocol development, training materials, and additional resources for participants to access. We provided participants with detailed verbal instructions and paper handouts containing information about the study and wearable devices. Pilot studies were crucial to inform us about common misconceptions and concerns about the wearable devices, which were incorporated into training manuals and materials for the full study.

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Partnering with community-based organizations can help inform protocol development, as community members are likely attuned to the technology literacy of the target population. Assumptions about baseline technological understanding should not be asserted; rather, researchers should collaborate with community members prior to developing training and resource materials to fully understand the target population's familiarity with devices and potential common misconceptions. We recruited and engaged a participant advisory board, which informed culturally accessible and appropriate protocols, procedures, and survey question methodology.

Particularly when a technology is unfamiliar, participants should be clearly informed and empowered to make decisions on when data is collected and how their participation is evident in their daily lives. While our study participants were generally enthusiastic about their involvement in research and enjoyed showing their wearable devices to others, many participants and the community members they interacted with were seeing wearable devices for the first time. This resulted in a range of responses, particularly from community members, from curiosity to mistrust. Additionally, participants encountered settings where they felt safest with the devices covered or removed. We instructed participants to remove the devices if they felt unsafe, and offered fabric covers to make the wearable less obvious when in public. However, many participants also felt that continuous wear of the device was important for their contribution to the study and were hesitant to remove the device. The voluntary nature of participation should be clear and unequivocal, and participants should be empowered to participate in a way that feels comfortable and least disruptive to them.

Study team members should also have clear and direct communication with participants to ensure that participants' safety is the highest priority. We encouraged open and frequent

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communication between the study team members, investigators, and UYDEL. Protocols were in place for any participant who voiced distress or concern regarding physical or mental health safety, which included notifying UYDEL social workers to help with psychological concerns, resource dissemination, linkage to proper care, and notifying authorities. While we primarily focused on encouraging participants to voice their concerns as they arose, future projects may also benefit from check-ins with participants on a regular basis to address any potential concerns.

We were also mindful of accessibility when designing the daily diaries. Questions were written with brief, non-overlapping multiple-choice answer options. While most of the participants were fluent in English, many were more comfortable using Luganda, the local language. Therefore, we printed the daily diaries in English with side-by-side translations to Luganda. Our inclusion criteria included completing primary school (at least Ugandan primary five basic literacy) and we designed daily diaries to have a reading level at or below primary five.

Conclusion

Through the process of designing and piloting a study using wearables and daily diaries, we uncovered several valuable lessons. As many others have noted, wearable devices have promise for data collection and potential for low-barrier intervention delivery in LMICs (Huhn et al. 2022b; Johnson et al. 2023; Liverani et al. 2021). However, few studies have implemented wearable technology with accompanying daily diaries in LMICs to study health behaviors associated with mental health.

All of our lessons involve being aware of, and responsive to, the context and lived experiences of study participants. For researchers and practitioners interested in leveraging these lessons in their own work, many of these areas can be addressed by engaging with community

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partners and employing study team members who are members of, or familiar with, the target population. Their valuable input can help to anticipate and reduce barriers for adoption of wearables and related technology.

Wearable technology offers significant opportunities for passive data collection on mental health correlates such as sleep and physical activity. While much of the existing work using wearable technology has been conducted in high-income settings, our experiences demonstrate how researchers can tailor data collection strategies for implementation in new contexts, such as low-resource settings. By designing around available resources, investing in data management and validation, and providing culturally accessible information, researchers and practitioners can overcome barriers and enhance the capacity for behavioral data collection in LMICs. Addressing disparities across contexts is crucial for meeting the tremendous unmet mental health needs in low-resource settings, where such innovative methodologies can play pivotal roles in identifying and improving health outcomes.

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Author Contribution statement

- KN – Conceptualization, writing – original draft
- KM – writing – original draft
- RC – writing – original draft
- JP – project administration, writing – review & editing
- GM – project administration, writing – review & editing
- AN – project administration, writing – review & editing
- MS – funding acquisition, supervision, writing – review & editing

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Conflict of Interest statement

Conflicts of Interest: None

Ethics Statement

Lessons learned are based on a study that was reviewed and approved by the research ethics committees of Makerere University School of Social Sciences (MAKSSREC MUSSS-2022-172, 27 October 2022) and Uganda National Council of Science and Technology (SS1560ES, 23 December 2022).

Data Availability statement

Data availability is not applicable to this article as no new data were created or analyzed in this study.

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