Feasibility Study

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Feasibility and acceptability of wearable devices and daily diaries to assess sleep and other health indicators among young women in the slums of Kampala, Uganda

Karen Nielsen[1], Kate Mobley[2], Rachel Culbreth[3], Jane Palmier[4], Anna Nabulya[5] and Monica H. Swahn[4]

Abstract

Background: Individuals in Uganda's urban slums have unmet mental health needs due to limited healthcare infrastructure, poor environmental conditions, and extreme poverty. Researchers often use wearable devices to measure factors associated with mental health including sleep, physical activity, and exposure to environmental stressors. However, the use of wearables for research purposes in low-resource settings is limited. This pilot study investigated the feasibility and acceptability of wearables and accompanying daily diaries to assess sleep and other health indicators in young women living in Kampala's slums.

Methods: Women ($n = 60$ total, two groups) aged 18–24 living in three urban slums participated in 5-day pilot protocols comprised of wearing Garmin vívoactive 3 smartwatches and completing daily diaries concerning sleep and physical activities. Participants completed surveys about their experiences. We based analyses on survey findings and data completeness.

Results: All participants responded to daily diaries. All but one reported wearing the device nonstop and 51 had recoverable heart rate data with median data coverage of 93.2%. Most devices (87.5%) recorded data for 5 days without running out of battery. Some participants (8.5%) found the wearable uncomfortable during the day, and 25% found it uncomfortable at night. Few participants (6.7%) reported feeling unsafe with the wearable, with most reports occurring prior to the availability of bracelet-like wearable covers.

Conclusions: Study protocols implementing wearables and complimentary daily diaries are feasible in this urban population. However, important contextual factors including participant and researcher training and safety concerns warrant additional considerations for acceptable utilization of wearable devices for research in other low-resource settings.

Keywords

Wearables < personalised medicine, mental health < psychology, technology < general, environment < lifestyle, diaries < personalised medicine, sleep duration, sleep quality, activity trackers, Uganda, feasibility studies

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Introduction

Unmet mental health concerns present substantial public health challenges in Uganda, where an estimated 23% of the population experiences mental illness.[1] Mental illness is also more prevalent among individuals in slum communities.[2,3] Slum households have been defined by the United Nations as households that possess "insecure residential status, inadequate access to safe water, inadequate access to sanitation and other infrastructure, poor

[1]School of Public Health, Georgia State University, Atlanta, GA, USA
[2] School of Data Science and Analytics, Kennesaw State University, Kennesaw, GA, USA
[3]Toxicology Investigators Consortium, American College of Medical Toxicology, Phoenix, AZ, USA
[4]Wellstar College of Health and Human Services, Kennesaw State University, Kennesaw, GA, USA
[5]Uganda Youth Development Link, Kampala, Uganda

Corresponding author:
Karen Nielsen, School of Public Health, Georgia State University, 140 Decatur St, Suite 457, Atlanta, GA 30303, USA.
Email: knielsen4@gsu.edu

structural quality of housing, [or] overcrowding."[4] Prior research of youth and young adults in urban slums in Uganda has found elevated rates of intimate partner violence, alcohol use, suicidal ideation, and food scarcity in these communities, underscoring a range of unmet health needs which necessitate effective and appropriate interventions.[5–8]

Although understudied, poor sleep and sleep-related problems are strongly linked to mental illness and are widespread in urban slums.[9–12] Many characteristics of slum communities, such as overcrowding, lack of access to food and water,[13] violence[7,8] and going to sleep hungry can increase the prevalence of poor sleep. A study conducted in an urban slum of southern India found that 24% of participants had poor sleep quality, and overcrowding was specifically associated with poor sleep quality.[14] A separate study of young adults in the United States found that food insecurity was correlated with poorer mental health and poorer sleep.[15] However, this has rarely been studied in slum communities in low- and middle-income countries (LMICs). The growing evidence of sleep-related problems in urban slums currently relies on self-reported measures of sleep,[16,17] which may be subjected to recall bias. Describing typical sleep quality and demonstrating ways to measure and improve sleep quality in individuals in slum communities can pave the way for mental health interventions and health programs.

Daily diaries are one methodological approach for examining sleep, physical activity, health and other contextual data. Daily diaries may consist of brief surveys conducted on a daily basis, either through self-reported questionnaires or active data collection approaches such as daily phone calls to the participant. The recency of data collected with this approach reduces recall bias while capturing specific behaviors and events.[18,19] Daily diaries have been implemented in studies within LMICs using a variety of technology. For example, a South African study collected daily reports of alcohol use, sexual activity, and HIV antiretroviral use using daily telephone calls to participants.[20,21] Another study in the Dominican Republic used paper daily diaries that were submitted via daily WhatsApp messages or a phone call to collect the activity space of female sex workers who had tested positive for HIV.[22] However, using mobile phones or text messaging for data collection may not be appropriate in low-resource settings where phone ownership may be limited.[23] Additionally, past research suggests that discrepancies still exist when measuring self-reported sleep using daily diaries compared to direct clinical measurements.[24–26]

Wearable devices are an objective alternative to assessing health behaviors via self-report in research. Wearable devices can collect large amounts of data on a range of health metrics such as heart rate, physical activity, and sleep and can be used to study both physical and mental health.[16] Consumer wearables and actigraphy also offer improved accuracy of sleep reporting compared to daily diaries.[26,27] As such, wearable technology presents an appealing, emerging option for passive and objective data collection of sleep and sleep quality. However, much of the current research to date using wearable technology for passive data collection has been conducted in high-resource contexts and a gap remains in adopting wearable technology for health research in LMICs.[28] Relatively few studies have been conducted in LMICs and in sub-Saharan Africa specifically. A recent review of mHealth use in Africa and Europe underscores this gap: authors identified 67 studies using wearable technology in Europe, but only 4 studies in Sub-Saharan Africa.[29]

Logistical barriers and low familiarity with wearable technology have slowed their adoption in LMICs. Gupta and colleagues note that while wearable physical activity monitors have improved in recent years, there are still many barriers to implementing wearable physical activity trackers globally, particularly in LMICs.[30] A study in Cambodia found that smartphone and internet access, which are needed for long-term data collection from most wearables, are not always available to people in LMICs, and many residents of LMICs may be unfamiliar with and untrusting of wearable technology.[31] Costs of wearables may also be a concern, though new devices at varying price points are entering the market and well-known brands can increasingly be purchased refurbished, in bulk, and through partnerships with vendors.

Despite these challenges, research teams are leveraging evolving technology and decreasing costs to implement wearable technology for passive data collection. One recent study sought to evaluate the feasibility and acceptability of using wearable technology in rural Burkina Faso.[32] Their study participants had an overall positive response to the wearables, with the majority of participants reporting that the wearables were non-irritating, easy to wear while sleeping, and had a positive appearance. However, the authors also reported data missingness due to technical issues and noncompliance. Other research has described the use of wearables as low-cost alternatives to costly medical equipment for monitoring vital signs of patients in Vietnam[33] and Ghana,[22] but more research in LMICs is needed on utilizing wearables to measure passive behavioral data for healthy study participants.

In LMICs, urban slums are critical contexts for addressing health disparities and improving health conditions using scalable strategies including vocational training programs. These settings also present unique situational environments and potential barriers to using wearable technology and daily diaries for data collection. Although research remains relatively sparse, recent studies indicate that wearable technology may be unfamiliar to many individuals living in such communities.[31] Moreover, lack of access to smartphones is another concern given that wearable devices are typically paired to smartphones for data collection and storage, and daily diaries are often submitted digitally or over the phone. Finally, many households in urban slums lack reliable electricity and as such may not be able to charge wearable devices during data collection. These are all important factors that need to be considered when assessing how to increase adoption of new technology for research and intervention delivery.

The goals of the presently described study were to examine the feasibility of using wearable technology and completing accompanying daily diaries among young women living in the slums of Kampala. The findings from these pilot studies were needed to inform the planning and implementation of a multiyear prospective longitudinal cohort study focused on the impact of vocational training on the mental health of young women living in the urban slums of Kampala, Uganda, who experience a disproportionate burden of poor mental health outcomes.[34,35] Another related goal was to identify the barriers for collecting data using wearable devices and daily diaries that may influence data completeness and quality.

Methods

A total of 60 participants were recruited for two pilot studies ($n = 30$ each). The pilot studies were designed to assess protocols for data acquisition and management plans, as well as the feasibility and acceptability of wearable devices and accompanying daily diaries, for the larger cohort study. The first pilot study took place in February 2023, and the second took place in May 2023. Participants were recruited by the Uganda Youth Development Link (UYDEL), a non-profit organization that provides vocational training and other services to youth and young adults living in the slums of Kampala, Uganda. UYDEL staff recruited participants by visiting residences that were within a 2000-meter radius of one of three of the UYDEL drop-in centers. In order to be eligible for the study, women had to be between 18 and 24 years of age and reside within 2000 meters of either the Banda, Bwaise, or Makindye UYDEL drop-in resource center. These criteria are consistent with the majority of women served by vocational training programs at UYDEL. Written informed consent was obtained from all participants. Findings from the TOPOWA Project pilot studies have been reported previously for the survey components that involve life satisfaction, depression, food insecurity, and lifestyle,[36] as well as participant experiences.[37] Focus groups were also conducted after study participation to further examine participants' perceptions of the wearable devices and daily diaries to ultimately inform modification of the study protocols. However, the present analysis is limited to data collected from wearables, daily diaries and post-participation surveys.

Wearables

Both pilots included sleep duration, sleep quality, and activity-related measures (e.g., heart rate and steps) using Garmin vívoactive 3 smartwatches worn continuously over 5 days and nights. The second pilot also included passive location tracking using the wearable device. The devices were selected based on availability, affordability, features, and the history of use of Garmin-branded wearables in research. Prior research has shown that consumer-grade wearables generally do not meet gold standards for research data collection (i.e. polysomnography for sleep), but still have utility for collecting behavioral data.[38]

The data collection duration was selected as a typical duration for the battery life of the selected wearable device; participants were not asked to charge wearable devices during the study period because not all residents of the Kampala slums have regular access to electricity. To conserve battery life, location was only collected during automatically detected activity events, defined as walking for more than 5 consecutive minutes or running for more than 1 min. The wearable devices were synced to Garmin Connect using a USB cable connected to a computer and Garmin Express, and data were retrieved through this platform for analysis.[39]

Daily diaries

Paper daily diaries were used to capture information that could be used to validate and supplement the data collected by the wearable device, including places the participant traveled to throughout the day, time the participant went to bed at night, time they woke up in the morning and self-rated sleep quality. Additionally, daily diaries captured self-reported daily stress levels. Daily diaries were printed with all text in both English and Luganda, the local language spoken in Kampala. Participants were given a booklet containing a series of paper daily diaries to be completed across the 5-day data collection period. The study personnel asked participants to complete all daily diary questions for each of the 5 days. Participants returned both the completed daily diaries and wearable devices at the end of the data collection period.

Surveys

Brief interviewer-administered surveys were completed after the 5-day data collection period. Surveys were conducted in both English and Luganda. Surveys collected information on demographics, baseline stress levels, and socioeconomic data including food insecurity and household support. Surveys also examined life satisfaction, depressive symptoms, and self-reported general sleep quality.[36] Additionally, surveys included questions intended to assess the acceptability of wearables, such as how comfortable the wearable was both during the day and at night and whether the participant felt safe wearing it. Research assistants entered de-identified data from the surveys and daily diaries directly into Research Electronic Data Capture (REDCap).[40]

Data analysis

The feasibility of wearables was measured using indicators of data completeness, data coverage and battery life. Heart rate data coverage was calculated by identifying all gaps of 15 min or more and summing all such elapsed times, less a 15-min tolerance, then dividing by the elapsed time between the first and last heart rate record and subtracting from 1.[32] The feasibility of obtaining wearable sleep data was calculated as the number of nights where participants had at least some sleep data. Battery life was operationalized using recorded steps as a proxy. Location data were extracted and summarized as the number of coordinates per person and days with recorded location data per person. Acceptability of wearables was operationalized through survey questions on device comfort, perceived safety while wearing the device, and overall participant experiences with the device across the 5-day period. Daily diary feasibility and acceptability were assessed using the number of data entries for the 5-day period for sleep, stress, and activities. Demographics and other participant characteristics were based on measures obtained from surveys. Data processing was completed in R 4.3.3 and Python 3.12.4, and analyses were conducted in R 4.3.3.

Results

Participant characteristics

Both pilot studies consisted of young women ages 18–24, described in Table 1. The mean age in both pilots was 20.1 years. Approximately one-third (31.7%) of participants had children. The median household size, including the participant herself, was four individuals. 26.7% of the young women reported having jobs. Moreover, 20% of participants had completed secondary or tertiary school. For local travel, 85% walked as their usual form of transportation and the remaining 15% reported primarily using boda bodas (motorcycle taxis). Less than 50% of participants overall reported owning a smartphone. Almost all participants (95%) had electricity in their household.

Feasibility of wearable device data collection

Pilot 1 data were collected from 27 out of 30 wearable devices. Pilot 2 data were collected from 29 out of 30 devices, though location and sleep data were only retained for 28. One wearable device was returned damaged, and data could not be recovered from the wearable device. The remaining data loss was associated with data management issues when participant data were overwritten due to mistaken identifiers.

In general, batteries lasted throughout the study period and beyond the fifth night. We used steps as a proxy for battery life (Table S1). The only difference in the wearable device settings between Pilot 1 and Pilot 2 was the addition of passive location tracking during automatically-detected activities. There is some indication that turning on the location tracking feature reduced battery life given the reduction in wearable devices (from 96.3% to 79.3%) that continued to collect data into the sixth day.

Only one participant reported removing the watch prior to the end of the study. This wearable device was returned damaged. A different participant reported removing the watch for an hour to charge it on the third day of their participation. All other participants reported wearing the watch during the day and at night from the time they received it until they returned it on the sixth day.

Wear time was also investigated via inspection of heart rate data. Optimal data collection resulted in heart rate records approximately every minute. Across both pilots, 51 participants had heart rate data. Heart rate data coverage ranged from 21.1% to 99.7%, with a mean of 80.0% and a median of 93.2%. Most participants ($n = 41$, 80.4%) had gaps of 1 hour or more in their heart rate data, and 17 participants (33.3%) had gaps of 8 h or more. Of the 51 participants with heart rate data, 41 (80.4%) had heart rate observations on the fifth study day, suggesting that they did not discontinue wearing the device prior to the end of the study.

Sleep data. We collected estimated sleep durations from the wearable devices for at least three nights for 96.4% of participants with any available data (Table S2). 19/27 pilot 1 and 16/28 pilot 2 participants (63.6% overall) had sleep data collected for all five nights that they wore the watch. However, sleep phases, which required simultaneous heart rate readings, were less frequently estimated: only 11/27 pilot 1 and 13/28 pilot 2 (43.6% overall) participants had sleep phase data produced for all five nights.

Location data from wearable devices. Location data were only collected from the wearable devices during the second pilot. A total of 192,314 location coordinates were recorded for 28 participants. The number of recorded location coordinates per person ranged from 619 to 51,060 (median: 4394, IQR: 5749.5), with locations recorded on an average of 2.5 days per person.

Feasibility and acceptability of daily diaries

All participants in both pilots reported on all 5 days of daily diary data collection and all study booklets were returned. Variables collected in the daily diaries had high completion percentages—for example, daily stress levels were reported

Table 1. Participant demographics and characteristics of TOPOWA pilot study participants ($N = 60$).

	Pilot 1 ($N = 30$)	Pilot 2 ($N = 30$)	Overall ($N = 60$)
Age			
Mean (SD)	20.1 (2.01)	20.1 (1.67)	20.1 (1.83)
Median [Min, Max]	20 [18, 24]	20 [18, 24]	20 [18, 24]
Number of people living in household			
Mean (SD)	5.20 (4.26)	4.33 (2.63)	4.77 (3.54)
Median [Min, Max]	4 [2, 25]	4 [2, 15]	4 [2, 25]
Children			
No	21 (70.0%)	20 (66.7%)	41 (68.3%)
Yes	9 (30.0%)	10 (33.3%)	19 (31.7%)
Employment			
No	24 (80.0%)	20 (66.7%)	44 (73.3%)
Yes	6 (20.0%)	10 (33.3%)	16 (26.7%)
Highest level of education			
Completed some primary	3 (10.0%)	6 (20.0%)	9 (15.0%)
Completed primary school	3 (10.0%)	6 (20.0%)	9 (15.0%)
Completed some secondary	14 (46.7%)	16 (53.3%)	30 (50.0%)
Completed secondary school	9 (30.0%)	2 (6.7%)	11 (18.3%)
Completed tertiary school	1 (3.3%)	0 (0%)	1 (1.7%)
Usual mode of transportation			
Boda boda	3 (10.0%)	6 (20.0%)	9 (15.0%)
Walking	27 (90.0%)	24 (80.0%)	51 (85.0%)
Owns a smartphone			
No	13 (43.3%)	21 (70.0%)	34 (56.7%)
Yes	17 (56.7%)	9 (30.0%)	26 (43.3%)
Household has electricity			
No	1 (3.3%)	2 (6.7%)	3 (5.0%)
Yes	29 (96.7%)	28 (93.3%)	57 (95.0%)

in 292 out of 300 daily entries across 60 participants. Self-rated sleep quality questions (measured using the Pittsburgh Sleep Quality Index)[41] each had greater than 89% completion by participants across the 5 days. Most participants (25/28 with wearable device location data and 51/60 overall) self-reported travel to destinations outside their homes on all 5 days, and all participants self-reported travel on at least 3 days. All participants reported sleeping during all five nights of the study period. Despite the high completion rates, some daily diaries contained inconsistent sleep times—for example, a participant reporting a 12-h difference in both sleep and wake times on consecutive days—that may be indicative of reporting errors.

Acceptability and participant experience of wearables

Participants generally found the wearable devices comfortable to wear, with only five participants (8.5% when accounting for non-response) rating the watch as "uncomfortable" or "very uncomfortable" to wear during the day (Table 2). This number increased to 15 (25%) when asked about comfort at night. Ten of the participants noting nighttime discomfort were in pilot 1, and only five were in pilot 2. Larger proportions of these participants had children and had smartphones compared to those who did not report nighttime discomfort, though no hypothesis tests were conducted for this exploratory analysis, and none reported having a job (Table S3). Qualitative feedback from several participants noted illumination from the watch as distracting to themselves or others around them. In response to this feedback from pilot 1, wrist covers designed to look like bracelets made of kitenge fabric were offered to participants to reduce nighttime illumination and improve device concealment for safety concerns during the second pilot. We also adjusted participant and research assistant training to clarify the types of data collected by the wearable devices, including detailed handouts and reference sheets for research assistants that include responses to participants' frequently asked questions.

Only four participants (6.8% of respondents) had ever seen a similar wearable device such as a smartwatch or fitness tracker (Table S4). During pilot 1, 86.7% reported being asked about the watch by others at some point during their study participation (Table S5).

Three participants in pilot 1 and 1 participant in pilot 2 (6.7% overall) responded that they felt "unsafe" while wearing the watch (Table 2). Higher proportions of those who reported feeling "safe" or "very safe" ($n=45$) had jobs, owned smartphones, and had completed less than secondary school, though no hypothesis tests were completed for this exploratory analysis. All participants aged 22 and older ($n=13$) reported feeling "safe" or "very safe" (Table S6). No participants reported feeling "very unsafe." Fabric wrist covers introduced in pilot 2 as an option for covering the watch were utilized by some participants, though more than half (56.7%) rated the covers as "uncomfortable" or "very uncomfortable" and all participants reported removing the wrist cover at least some of the time (Table S7). Additionally, 15% of participants reported avoiding certain locations while wearing the watch (Table S4).

Table 2. Comfort and safety when wearing the wearable device in TOPOWA pilot studies ($N=60$).

	Pilot 1 ($N=30$)	Pilot 2 ($N=30$)	Overall ($N=60$)
How comfortable is the watch to wear during the day?			
Very comfortable	11 (36.7%)	11 (36.7%)	22 (36.7%)
Comfortable	11 (36.7%)	15 (50.0%)	26 (43.3%)
Neutral	5 (16.7%)	1 (3.3%)	6 (10.0%)
Uncomfortable	3 (10.0%)	1 (3.3%)	4 (6.7%)
Very uncomfortable	0 (0%)	1 (3.3%)	1 (1.7%)
Missing	0 (0%)	1 (3.3%)	1 (1.7%)
How comfortable is the watch to wear at night?			
Very comfortable	8 (26.7%)	7 (23.3%)	15 (25.0%)
Comfortable	10 (33.3%)	16 (53.3%)	26 (43.3%)
Neutral	2 (6.7%)	2 (6.7%)	4 (6.7%)
Uncomfortable	10 (33.3%)	5 (16.7%)	15 (25.0%)
Very uncomfortable	0 (0%)	0 (0%)	0 (0%)
How safe did you feel while wearing the watch?			
Very safe	7 (23.3%)	9 (30.0%)	16 (26.7%)
Safe	12 (40.0%)	18 (60.0%)	30 (50.0%)
Neutral	8 (26.7%)	2 (6.7%)	10 (16.7%)
Unsafe	3 (10.0%)	1 (3.3%)	4 (6.7%)
Very unsafe	0 (0%)	0 (0%)	0 (0%)

Discussion

These pilot studies were intended to explore the feasibility and acceptability of wrist-worn wearable devices and accompanying daily diaries for capturing sleep, activity, and travel behaviors among young women living in the slums of Kampala, Uganda.

Through surveys, we were able to ascertain the acceptability of wearable devices by examining participants' perceptions while wearing the devices for 5 days. We found that less than half of the participants owned smartphones, meaning that it is not practical at this time for studies in this area to attempt to leverage participant-owned smartphones for data collection, storage, or transmission with wearable sensors or daily diaries. Access to mobile phones and phone ownership in this population has not increased over the last decade.[23] Contrary to expectations, most participants reported having electricity in their homes, meaning that studies of longer durations that require devices to be charged during data collection may be possible, depending on the device's internal data storage capacity and individual household electricity capabilities.

The overall high self-reported ratings suggest that wrist-worn wearable devices are acceptably comfortable for continuous wear over 5 days by this population for research data collection, though there may be demographic differences in who finds the devices uncomfortable—particularly at night. Participants reported that watches were more uncomfortable at night than during the day. The Garmin vívoactive 3 devices used in this study have a display diameter of 30.4 mm and may be cumbersome to wear for those with small wrist circumference, and those unaccustomed to wearing a watch.

While the majority of participants did not express safety concerns in survey questions, a few participants did report feeling unsafe and 15% stated that they avoided locations because they were wearing the watch. Further, the potential for safety-related concerns may be underrepresented due to participants who are more comfortable with the wearables self-selecting into the study or the presence of response biases. We took steps to reduce concerns after the first pilot, introducing optional fabric covers and including additional training for participants and research assistants. Nighttime discomfort and safety concerns were both lower during pilot 2. However, more participants reported avoiding locations during the second pilot, suggesting that participants may have engaged in behavior change to preemptively avoid situations that could feel unsafe when wearing the watch as a result of increased emphasis on safety in training materials. Given the novelty of these devices and potential for theft and scrutiny by community members, future studies should prioritize understanding and addressing contextual safety concerns to ensure safety acceptability. Exploratory analyses suggest that perceived safety may vary across demographics. Our full study will iterate on the changes made to the training materials to further address safety considerations, including emphasis on the option to remove the device at any time without loss of compensation for participation.

We also found that wearable technology was feasible for research purposes in this population. Data loss for the entire study duration was minimal. Heart rate data coverage was highly variable, with a median coverage across individuals' observed participation periods of 93.2%. Coverage gaps may include both wear issues such as loose fit of the device and possible temporary removal of the device. However, there were no patterns in coverage across time of day that could suggest nighttime removal, most participants with heart rate data had observations on the final study day, and only one participant reported that she stopped wearing her assigned wearable device prior to the end of the study. Our heart rate data coverage is notably higher than prior studies using wearables in LMICs that used the same measure and obtained mean data coverage of 3%[32] and 7%.[42] There are many possible reasons for this difference, ranging from participant compliance to the choice of device. Missing data overall were consistent with prior work in both LMICs and high-income settings.[32,43,44] Data loss due to data management errors also occurred during the pilot studies. While the Garmin Cloud portal served as a convenient repository for data sharing and quick quality control visualization, mistakes in setup can lead to data loss such as sleep being overwritten. We found that separate manual backups of data are critical to avoid this source of data loss, a step to be implemented in the full study.

Daily diaries were feasible to implement, with all booklets returned at the end of the study period. All participants responded to daily diary questions for the five study days with high completion rates on individual questions – suggesting that the daily diaries were acceptable. However, some discrepancies existed with participants reporting unusually long sleep durations (e.g. more than a 12-h window between the time of falling asleep and time of waking) or unusual variations in the timing of sleep (e.g. changes of 12 h in sleep and wake times on consecutive days). These may be reflective of documentation errors when participants recorded times, or potentially limited time literacy. The second pilot study incorporated several additional questions on the timing of sleep (e.g. "Was it dark outside when you went to sleep?"). This ultimately helped evaluate discrepancies in sleep timing and unusual reported values. Therefore, while daily diaries appear to be an acceptable method of data collection for this population, specific questions may require additional workshopping and consultation with community partners to ensure that accurate data are collected.

While studies using wearable devices and daily diaries with this population appear largely feasible and acceptable, we noted multiple areas in which the wearable devices or daily diaries alone may be inaccurate or lack sufficient context. As an example, compared to reported travel activities in daily diaries, the wearable devices recorded substantially less travel. Possible reasons for this missing travel include battery life, travel that did not trigger automatic activity detection due to limited duration, and travel by means other than walking (e.g., boda boda motorcycle taxis which are commonly used in Kampala and often the cheapest option for transportation). Therefore, both passively collected location data and self-reported travel behavior are needed to capture a balance of detailed travel for environmental exposures and overall behavior if this tracking is of use to the research.

The wearable devices were able to estimate sleep duration for most nights, but sleep phases were less frequently identified. In addition to data loss when batteries were expended, lack of sleep phase identification may have been due to reduced accuracy of optical heart rate sensors applied to individuals with darker skin tones[45] or documented issues with sleep phase accuracy from such wearable devices,[44] highlighting the importance of selecting devices based on existing research concerning their validity and reliability and their planned use case and context. Further, we believe that some participants may have worn the wearable devices too loosely, which could result in data quality issues or data loss. Providing clear guidance on proper wear of the device is important for minimizing such issues, and our full study will emphasize correct wear for both research team members and participants.

Daily diaries also contained occasional data quality concerns, such as participants reporting dramatic day-to-day shifts in sleep and wake times on consecutive days that were not consistent with wearable data. Prior research has noted that people tend to be inaccurate when estimating their sleep times.[24–27] To reduce possible biases in the daily diary items, future studies could add automated reminders on the wearables to ensure that participants complete the questions on time, ensure that training for participants addresses any confusion related to questions in the daily diaries, and encourage participants to use the wearables as watches to note the times when they went to bed and woke. This collection of tradeoffs justifies using wearables to collect sleep data with daily diaries as backups to fill in missing data, rather than relying exclusively on self-reported data, despite self-reporting having less missing data.

Conclusion

We found that using wrist-worn wearable devices and accompanying daily diaries to capture sleep, activity, and travel behaviors among young women living in the slums of Kampala, Uganda is feasible. Safety considerations should be reviewed to ensure the acceptability of wearable devices in new contexts. Wearables and daily diaries provide complementary information that can be used to better understand sleep and activity patterns. Changes in these patterns may serve as indicators of successful implementation for mental and other health prevention and intervention programs suitable for this population.

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Guarantor: MS.

ORCID iD: Karen Nielsen https://orcid.org/0000-0003-3771-5272

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