

Assessing and Maximizing the Acceptability of Global Positioning System Device Use for Studying the Role of Human Movement in Dengue Virus Transmission in Iquitos, Peru

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Abstract. As use of global positioning system (GPS) technology to study disease transmission increases, it is important to assess possible barriers to its use from the perspective of potential study participants. Fifteen focus group discussions stratified by sex, age, and motherhood status were conducted in 2008 in Iquitos, Peru. All participants said they would accept using a GPS unit for study purposes for 2–4 weeks. Participants' main concerns included caring properly for the unit, whether the unit would audio/videotape them, health effects of prolonged use, responsibility for units, and confidentiality of information. A pilot study was then conducted in which 126 persons were asked to carry GPS units for 2–4 weeks; 98% provided consent. All persons used the units expressing minimal concerns, although 44% reported forgetting the device at least once. Our study is the first to highlight participant concerns related to use of GPS for long-term monitoring of individual behavior in a resource-limited setting.

INTRODUCTION

The movement of individual humans during regular daily activity patterns is an important underlying factor influencing the risk of exposure to vector-borne pathogens.¹ This is particularly true for pathogens transmitted by the mosquito *Aedes aegypti*, such as dengue virus, because it bites during the day and moves short distances.^{1,2} It is expected that the multiple locations that persons visit during their regular daytime activities, such as the homes of neighbors or relatives, schools, markets, or workplaces, locations defined as their activity space,¹ will affect their risk of exposure to infective mosquito bites. However, risk of exposure measured across a person's activity space has not been rigorously quantified for pathogens transmitted by *Ae. aegypti*.² This is a problem, at least in part, because identifying and quantifying exposure rates for a population, i.e., movements of persons within their activity space, is logistically and technically challenging. Although instruments for tracking individual movements that rely on individual recall have long been available, these are imperfect because of bias in the recollection of movements and the limitations of human memory. Because observation of a person's movements, especially over extended periods of time, is unfeasible, location-aware technologies such as the global positioning system (GPS) provide promising alternative methods for studying activity space. Global positioning systems have increasingly become more accessible and useable for studies of individual human movement patterns.^{1,3}

A central concern related to the application of location-aware technology to study the relationships between movement and disease is the actual acceptability and use of devices by study participants. Identification of the activity spaces of persons requires monitoring of individual movements for extended periods.⁴ Moreover, to minimize bias and errors in the tracking record, monitoring should capture a representative sample of movements, i.e., they should be used continu-

ously. Thus, for GPS or other such tracking methods to be truly useful for research, they must be acceptable to study populations to minimize bias in coverage and ensure proper compliance with study protocols. Generally, if participants have a device that is not objectionable for long-term wear, is attractive, requires minimal effort on the participants behalf, and participants do not need to worry about (i.e., breaking it), we expect acceptance to be high and errors in the tracking record caused by use problems to be minimized.

In particular, GPS is a promising technology because it can cheaply provide precise, continuous, long-term positional measurements anywhere in the world.¹ However, despite its potential, the use of GPS in studies of human health has been limited,^{5–7} especially in resource-challenged settings. Generally, GPS units previously tested were uncomfortable and bulky, and included a receiver, battery pack, and antenna placed in a vest or pack for wear on the back or waist. Reported participant complaints in the latter studies were mostly associated with comfort or aesthetics.^{8–10} In these few previous studies, sample sizes were small (2–31 participants), monitoring periods were short (< 24 hours),^{5,7–9,11–13} and none of the studies assessed participant acceptance of GPS units. Therefore, although the authors of all studies encouraged further use of GPS because all obtained location data,^{5,7–9,11–13} it remains unclear whether long-term use of GPS would have been acceptable to study participants.

We report results from a study assessing the acceptability of use of GPS units with the long-term goal of determining the role of human movement patterns in the transmission dynamics and spatial/temporal patterns of dengue. The objectives of this study were 1) to determine whether it would be acceptable to persons living in Iquitos, Peru, to use a small GPS unit for one month, and 2) to explore what types of concerns potential participants would have regarding the use of GPS units.

METHODS

Study area. Our study was performed in the Amazon city of Iquitos (73.2°W, 3.7°S, 120 meters above sea level) in the Department of Loreto in northeastern Peru. Iquitos is a

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geographically isolated city of approximately 370,000 people in the Amazon Basin of Peru that is accessible only by boat or plane, and whose main industries are small commercial enterprises, fishing, oil, lumber, and some agriculture.^{14,15} Our study took place in two Iquitos neighborhoods, Tupac Amaru and Maynas, that were previously described in detail.^{16,17} Both neighborhoods have had high rates of dengue transmission.^{15,17,18}

Study design. Our study consisted of 1) focus group discussions (see description below) and 2) a pilot study comparing findings about human movement using survey-based interviews versus GPS units, and through which we also assessed participant acceptance of GPS units. In this study we define movement in terms of locations visited and the time spent there.¹

Global positioning system unit. Because this study is part of a larger study, many discussions and prototyping of candidate GPS device designs took place within the research team before the focus group discussions. Briefly, we pre-selected devices that were low cost, had reasonably long battery life, were durable in tropical weather conditions, had adequate spatial and temporal accuracy, and were small, lightweight, and innocuous.¹⁹ Devices were evaluated for their ability to track persons moving about Iquitos and the errors associated with measurement under different conditions. These data are reported separately.¹⁹ All devices evaluated proved suitable for tracking in Iquitos. Options for deployment of GPS units included purses, belt attachments, lanyards, and others deemed consistent with standard apparel in Iquitos.

Focus groups. A total of 144 permanent Iquitos residents participated in the 15 focus group discussions carried out the last week of January 2008. Participants were grouped by age and sex: three groups of 18–30-year-old men, two groups of 18–30-year-old women, two groups of 31–45-year-old men, two groups of 31–45-year-old women, two groups of 46–59-year-old men, two groups of 46–59-year-old women, and two groups of mothers. One of the mothers' groups consisted of women whose children were young (3–8 years old) and the second group consisted of women who had older children (8–18 years old).

Purposive sampling, a non-probabilistic sampling method commonly used in qualitative research, was used to select members for all focus groups.^{20,21} Fifteen persons meeting the age and sex inclusion criteria for the upcoming focus group were recruited from one of the neighborhoods the day before each event, with the goal of having approximately 10 participants at the discussion the next day. We planned on two groups per age group and sex, and a total of two mother's groups of children of different ages, but because all the young men (18–30 years old) recruited in one community came to the focus groups, we split this large group into two focus groups, and thus had a total of three focus groups of 18–30-year-old men.

Recruited participants met in a central location within their communities and were transported to the location where the focus group discussions took place. Each focus group was facilitated by a Peruvian social scientist in Spanish, and one of the research team members, all of whom were native to Iquitos, took detailed notes of each discussion. Before initiating each focus group discussion, an Institutional Review Board–approved consent form was read and participants provided verbal consent to participating in the study and being audiotaped.

Pilot study. In preparation for a larger longitudinal cohort study that will determine the role of activity space in dengue transmission dynamics, a pilot study was conducted during August–December 2008 to test logistics and training issues. One hundred twenty-four participants were enrolled from the same two neighborhoods where the focus groups were conducted. The GPS units were distributed to participants for 14 days ($n = 62$) or 30 days ($n = 62$).

Participant selection was not random: each month, eight research assistants were asked to recruit 3–4 persons with specific sex and age characteristics from city blocks participating in a prospective dengue surveillance cohort. We sought to enroll 120 participants with even representation across study neighborhoods, sex, and three age groups (18–30, 31–45, and 46–59 years of age). No children were included because it was felt that adults were most likely to show a full range of mobility, and they would have the highest ability to comply with the study procedures. Children will be included in future studies.

Potential participants were visited by a trained research assistant the next day and received a pamphlet containing specific information about the GPS unit that was given to them (Figure 1). Those persons who agreed to participate were then asked to provide written consent to participate and enrolled into the study (Figure 2). Half of the participants were asked to use GPS units for a period of a month, whereas the other half was asked to use GPS units for two weeks. The research team scheduled an exchange of the GPS units every three days to download data, verify function, and recharge batteries. At the time of GPS unit exchange, participants were asked about their experiences with the GPS units, whether they had used it, if they had forgotten to take it with them during their daily activities and, if so, on what days.

Data analysis. After each focus group, the study team met to expand notes recorded and produce a detailed report for each of the focus group discussions by using the notes and audio recordings. Data were analyzed based on specific themes outlined on the focus group guide: 1) questions and concerns regarding GPS use, 2) ideas regarding how to wear/carry the GPS unit constantly for an extended period (or in the case of the mothers' groups, a reliable way for the GPS to be worn by children), and 3) key messages to be stressed before distributing GPS units. Trends in the data were documented, both in general terms, as well as stratified by sub-groups.

For the pilot study, we documented and recorded the frequencies of the total number of participants who were asked to participate, the number who accepted, the number who declined, and the reasons for not wanting to participate. For each participant, we also documented whether they had forgotten to use the unit in the previous three days and, if so, why. We tabulated the counts of reports of forgetting to use the unit, and then ran a Poisson generalized linear model to estimate bivariate and multivariate associations. A final debriefing was conducted with all research assistants involved in the pilot study to document reasons participants gave for declining participation and related issues they recorded with regard to participants' use of GPS units.

Ethical approval. Institutional Review Board approval for this study was obtained from the University of California at Davis (2007.15244), the U.S. Naval Medical Research Center Detachment in Lima (NMRCDC 2007.007), Emory University, San Diego State University, and Tulane University School of Public Health and Tropical Medicine.

RESULTS

Concerns and questions associated with GPS use from focus groups. Men and women alike responded positively and affirmatively about their willingness to use a GPS unit for a period of a month. The list of concerns was long in all groups, but the level of concern overall was low. The two main concerns (issues brought up most frequently and discussed most extensively in all groups) were 1) whether the GPS unit could tape their conversations or in some way record what they were doing, and 2) how to charge, properly handle, and use the unit. Other concerns raised in most groups, but not all, included health/safety, confidentiality/privacy, responsibility for the unit, and compensation or personal benefit for using the GPS unit (Table 1).

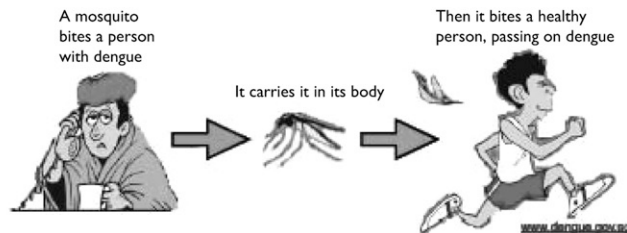
Although each focus group discussion started with a brief description of what the GPS units were and how they were used, as we handed out a unit for participants to hold, we had to clearly emphasize numerous times in each group that the GPS unit could not audio- or videotape them in any way. Despite this assurance, in most groups, people repeatedly asked whether we would be able to hear conversations they had or see with whom or where they had been. Also, in the three focus groups with young men (18–30 years old), they

asked about us being able to hear or see them in real time and possibly spy on them or track them.

The other main concern was whether the participants would receive adequate instructions for caring for and using the units correctly. Some questions related to charging the unit: how and how often and how would they know to charge it? Most participants indicated they would be willing to charge the units themselves with proper instruction, with the exception of older women, most of whom preferred that it be charged for them because they might forget, but also because of a concern that they would charge it incorrectly. There was also extensive concern about accidentally turning the units off, especially by those with small, curious children around. They wanted to know if they would be taught how to recognize when it was off and how to turn it back on. There was also discussion, among men and women of all ages, as well as mothers of 3–8-year-old children, about the durability of the GPS unit. They were concerned that the unit would not withstand being exposed to heavy rains, water (for those who work on the river and sometimes get wet), heat, or sweat. Finally, there were numerous questions about whether they had to use the unit constantly, or if they could take it off periodically, such as when at home. In a few groups, people asked about unit use when outside of city limits, concerned that the unit might not pick up a signal

About Dengue

Dengue is transmitted when you are bitten by a mosquito infected with dengue



Classic Dengue

- Fever
- Chills
- Fatigue
- Rash
- Headache
- Eye pain
- Body ache
- Joint pain
- Nausea/vomiting

Warning Signs

- Intense headache
- Abdominal pain
- Nose or mouth bleeds or blood in your vomit
- Strong desire to sleep
- Vomiting
- Difficulty breathing

****If you have any warning signs you should go immediately to the nearest hospital or health center****

Breeding grounds for mosquitoes

are water containers such as:

- Tanks
- Buckets
- Drums
- Disposables

You can **prevent dengue** by throwing out or cleaning these containers frequently



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PROYECTO DENGUE IQUITOS, PERU



The *Aedes aegypti* mosquito transmits dengue to humans



Information about the GPS unit

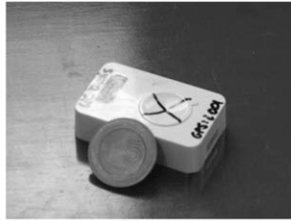
You can participate in this important study about dengue. The participants in this study will use a device called "GPS". Here we will answer some questions you might have about GPS.

FIGURE 1. **A.** Global positioning system (GPS) pamphlet distributed to pilot study participants, including picture of GPS unit used during study (external view). **B.** GPS pamphlet distributed to pilot study participants, including picture of GPS unit used during study (inside view).

About GPS

What is “GPS”?

- GPS stands for Global Positioning System
- It is a small device that identifies where you are using signals from satellites.
- When it's used with a special program, you can see little points on a map marking the exact places where the device has been.
- It cannot be used for anything else and has no value outside of this study.



Example of a GPS unit

Can it record other things?

- GPS **cannot** record conversations.
- GPS **cannot** take pictures.
- GPS **cannot** determine what a person is doing in the place it identifies.
- GPS **cannot** say where you are or lead someone to your location.
- GPS **ONLY** makes small points on a map showing where you have been.

Why do we want to use GPS?

- There is a lot of dengue in Iquitos. Information from the GPS unit will help us to better fight dengue.
- We want to know where people in your community go so that we can visit these sites later.
- This information will not be used for anything bad.

Will it have any effect on my health?

- No, the GPS unit will not cause any health problems or cause inconvenience.
- Using a GPS unit is like using a cell phone.

Who will know where I've been?

- Only the study's investigators will see the locations identified by the GPS. This information will not be shared with anyone.
- All information is totally confidential.

If someone has a computer or program, can they see where I have been?

- No one can see where you have been. Only the investigators have access to the information recorded by the GPS unit.

How can using the GPS unit help me?

- Using the GPS unit will help us fight dengue in Iquitos. The main purpose is to obtain information to promote the well-being of the community.
- At the end of your participation, we will give you a basket of groceries and personal hygiene items as a thank you.

What happens if the device breaks?

- We don't want you to worry if the unit works or not, or if it is on or not.
- It is our responsibility if it breaks. It is your obligation to use it.

What if it is stolen or lost?

- You will not have to pay for the GPS unit, but you will not receive a gift basket.

What do I have to do?

- You have to wear it all day everyday, except when you are at home. You may take it off at home.
- Every 3-4 days, someone will bring you a charged GPS unit and pick up the one you already have.
- You can wear the unit in many ways: for example, around your neck, hooked to your belt, or carried in a bag.
- You do not have to turn it on or turn it off.



GPS unit on a cord, around the neck

FIGURE 1. Continued.

outside of Iquitos or that they would not be around when the unit needed to be charged.

Health questions were broad, such as whether using the GPS units could be harmful in any way to one's health, as well as specific, such as whether prolonged use could cause fertility problems, cancer, heart problems, skin irritation, affect one's organs, or even attract lightning. Mothers of young children, who did not have any specific concerns about having their children use the GPS units, instead expressed concern about what their child might do to the unit. Despite the numerous health-related questions, the level of concern was low.

Participants also expressed concern that the research team, family members, bosses, or friends might find out personal things about them, including the possibility that a family member or friend might download information from the unit. We explained that only the research team would be able to download the data from the GPS units, and that this information would not be shared with anyone. Moreover, the data would show us where they were at (location), but we would not be able to know who they were with, what they were doing, or what relationship they had with that person, nor would this information be shared with anyone else. We also clarified that although the research team would be able to reconstruct where the user had gone while wearing the GPS unit, we would not be able to track them in real time. The reverse was the case in one of the mother's groups (3–8 year-old children): they

were not concerned about the confidentiality of the data for their children, but rather were interested in seeing the data. We explained that all data would be confidential, including the children's data.

There were a few other issues discussed in some focus groups that warrant mentioning. In most of the men's groups, at least one man asked what they would personally get from using a unit. Other men in the group would often respond to those men about the benefit to the community to reduce dengue. However, there seemed to be agreement that it would be nice for them to get something for our role in this study that benefits their community. This issue of personal benefit or compensation did not come up in any of the women's groups. Related to this point, we did provide a gift basket with toiletries or food items to all participants in the pilot study as an incentive to improve compliance.

Another observed difference in the responses seemed to be related to age and sex. All men in the younger age group (18–30 years old) responded that they would be willing to use the GPS, but further probing revealed that some of them might initially accept the GPS, but not actually use it properly. Several mentioned that it was likely that some young men might initially act serious and consent to the use in front of the researchers, but subsequently might not actually take the GPS seriously.

Possibly related to responsible use of the GPS unit based on the flow of the discussions, in all of the young men's groups

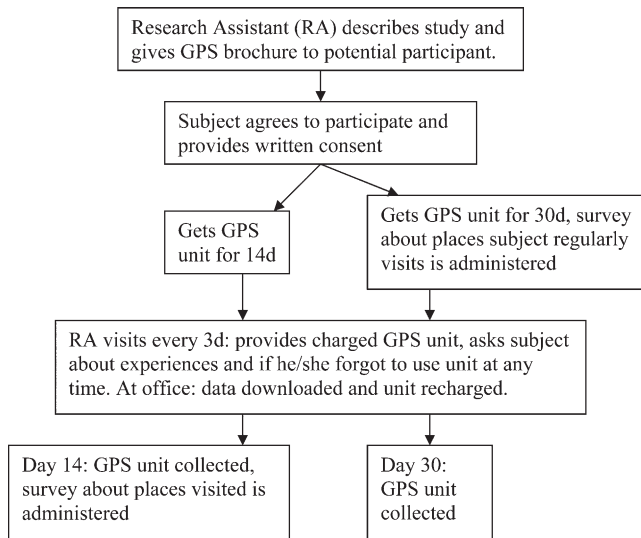


FIGURE 2. Flow diagram depicting study procedures. GPS = global positioning system.

(18–30 years old), there were questions about who was responsible for the unit if it got lost, and whether participants would have to pay for a lost or stolen unit. In various groups, we were asked if the people receiving the GPS unit would be asked to sign a contract committing to wearing it and returning it when it was requested back. Young men, in particular, felt that issues of responsibility for the unit and whether one would still get a gift for participating in the study if the GPS was lost or stolen should be clearly stated in this contract.

In some women's groups, women commented that jealousy from their partners/spouses might be a problem: some men might not trust that their wives had been asked to participate in a study and might not believe this was a GPS unit to reconstruct where they had been. They suggested that the research team either invite the woman to participate in the presence of her partner, or that the research team give out some type of document that provided evidence that this GPS unit was part of a research study, which was done in the pilot study. In a few groups, men and women discussed the fact that those selected to use GPS units might actually gain status in the community and that others might also want to use a GPS and might be concerned that they were not selected to use this novel technological device.

Several women's and men's groups talked about ways to protect the unit from being stolen, focusing on ways in which they could wear the unit in inconspicuous ways. However, the issue of the user's safety only came up in one of the men's groups and the mothers of 8–18-year-old children. The men's group participants discussed their concern about being harmed by others who might want to steal the GPS unit.

In most of the men's focus groups, there were typically one or two men who had already heard of or even used GPS technology. Among the younger men (18–30 years old), they might have heard about it or seen one used in a movie. Among the older men (31–45 and 46–59 years old), some men had seen them used or used them themselves in their jobs, such as to reference locations (logging industry or road construction), and a few had seen them used in movies.

Other issues discussed with less frequency and intensity included whether the GPS unit might interfere with other electronic devices in their homes or *vice versa*, that the operation of an electronic device near the GPS unit might interfere with its functioning, and what the effect of overheating might be on the unit.

Although mothers of children 3–8 years of age asked whether GPS units could have negative health effects on their child, they seemed much more concerned about what their child might do to the unit or not use it. In general, mothers felt that they would have to remind their children to wear it on a daily basis.

Suggestions regarding how to wear the GPS unit for an extended period of time. During the focus groups, we explored ideas regarding the most comfortable and convenient way to use a GPS unit for 14–30 days. Responses varied by age and sex, and the discussions about options centered around carrying the GPS unit in a way that was convenient (i.e., keeping one's hands free, not forgetting it), safe from possible theft, and that did not draw attention to it. The top choices included wearing it on a strap around one's neck (lanyard) or on a waist belt-clip. There were few disadvantages discussed about the lanyard, and among the younger persons (18–30 years old), we were told this is actually a fashionable way to carry one's cell phone. The waist belt-clip was a popular choice for men because many carry their cell phones this way. Another suggestion was to carry it in one's secret pocket (most women and many men have a pocket sewn into their clothes to carry their money, usually located near the waist band) or in a woman's bra.

TABLE 1

Questions and concerns regarding use of a global positioning system device reported as number of groups in which the issue was discussed at least once, Iquitos, Peru

Questions and concerns	Women, age, years			Men, age, years			Mothers of		Total
	18–30 (n = 2)	31–45 (n = 2)	46–59 (n = 2)	18–30* (n = 3)	31–45 (n = 2)	46–59 (n = 2)	Children 3–8 years of age (n = 1)	Children 8–18 years of age (n = 1)	
Proper care and use of unit†	2	1	2	3	2	2	1	0	13
Audio or video taping	2	0	1	3	2	2	0	0	10
Confidentiality or privacy	0	2	1	3	1	1	0	0	8
Health	2	1	1	1	0	1	0	1	7
Responsibility for unit‡	0	0	0	3	2	1	0	1	7
Compensation or personal benefit	0	0	0	3	1	1	0	0	5
Jealousy	1	0	2	0	0	0	0	0	3
One's safety	0	0	0	0	1	0	0	1	2

*There were two focus groups per age group, except among the 18–25-year-old men, where we had three focus groups. We also had one focus group for mothers of children 3–8 years of age and one for mothers of children 8–18 years of age.

† Includes questions/concerns on how to charge it; how to know when it is on or off; durability of unit to rain, water, or daily wear; whether it works outside Iquitos, and whether one must use it all the time.

‡ Who pays for unit if it is stolen or if it breaks.

When we asked about how children 8–18 years of age might carry it, mothers felt that having their young daughters carry it in a small purse (12–18 years old) or small, bright backpack (8–12 year old) would work, but also noted that there were many times of day when their daughters may go somewhere without their purse. Mothers of girls 8–18 years of age also felt that their daughters could be convinced to use and care for it properly. However, mothers of 8–18 year-old boys coincided with mothers of children 3–8 years of age that the only way to ensure their children wore it was to sew it into the clothes, but felt that it might work to have the boys wear it on a lanyard under their clothes. The suggestion of sewing it on or into the clothes was strongly supported by most women, who also did not think it would be much of an inconvenience to sew in the GPS to their child's clothes on a daily basis.

GPS development. Based on insights provided by participants in focus groups, we identified a commercially available GPS device that met most of our key criteria (I-GotU 100; Mobile Action Technologies, Taipei, Taiwan) (Figure 1). These units had the longest battery life for their size in the market (approximately 3 days at a 2.5-minute collection interval), had memory for capturing 16,000 tracks, were small and lightweight (< 5 cm and 21 grams), were water-resistant, and enabled password protection for safeguard of personal GPS data.¹⁹ Based on consensus across focus groups, we distributed GPS units with lanyards for persons to carry around their necks.

Pilot study. Only 2 persons (1.6%) considered for participation declined; a 23-year-old man who was interested in using the GPS unit but did not want to be interviewed, and a 35-year-old man who was going to be traveling and not be home for unit exchange. Questions asked by participants when GPS units were distributed and exchanged were similar to those voiced in the focus group discussions and covered in the pamphlet. During GPS unit exchange, questions similar to those asked in focus groups were repeated, although one new question focused on a flickering of light that the GPS emitted regularly: whether this light could cause cancer or whether this light was dangerous for pregnant women.

All participants reported using the GPS device when they had them and some admitted they did not use the devices occasionally (e.g., for an afternoon) either because they thought it was no longer working, it was due for exchange, or they simply forgot. Overall, 9.6% of the times GPS units were issued (i.e., new units were issued every three days), participants reported forgetting or not using the unit at least once in the 14–30-day period. Forty-four percent of participants reported forgetting or not using the GPS on at least one occasion, and 16% on more than one occasion. There was a significant positive relationship between the length of the observation period and the frequency devices were forgotten ($P < 0.01$), with 35% of participants forgetting the device at least once when required to carry it for two weeks versus 52% when using it for one month. Only those carrying devices for one month forgot to use them on more than three occasions (5% of participants). Men reported forgetting to use the GPS less often than women ($P = 0.03$) and middle-aged (31–45 years of age) participants tended to be less likely to report forgetting than other age groups, although this was not significant ($P = 0.08$). Examination of the GPS tracking records (Figure 3) indicated that all participants did carry units with them because multiple locations in their tracking records are identifiable (defined as > 5 points recorded by the GPS occurring within 100 meters



FIGURE 3. Daily individual mobility pattern for a randomly selected resident of Iquitos, Peru, tracked with a global positioning system for a 15-day period during September–October 2008.

of each other, when points were recorded every 2.5 minutes). Based on our preliminary analysis, most instances in which devices did not record points or indicate movement were caused by the devices not tracking as opposed to participants not using them on a continuous basis.¹⁹

To explore GPS non-use more thoroughly, we asked research assistants who recruited and exchanged GPS units for input on non-use based on their observations and interactions with participants. They reported that the pilot study participants openly admitted to not using GPS units at times. The two most common reasons were 1) forgetfulness when rushing out for a specific activity, and 2) specifically among young men, embarrassment about some of the places where they went. One young man specifically admitted that despite being assured that the GPS did not tape, he did not use it to visit his lover because of this concern. Another reason given by a few persons was that in the comfort of a relative's home, they took off the GPS unit and then forgot it was there. There were two mentions of security. One man who liked to drink admitted he was concerned that his drinking friends would want to steal the GPS unit, and another man stated that someone had tried to rob him and he felt it was because the GPS emitted a light that made the thief think he had a digital camera around his neck.

A serious concern was shown by participants about making sure that the GPS unit was working properly. One person stopped wearing his unit because he thought, correctly, that the GPS unit had been accidentally turned off when it stopped emitting the light. During the first days of the pilot trial, before

we deactivated the button that could accidentally turn off the GPS, a few GPS units were accidentally turned off, and in a few occasions, participants asked about or sent back their GPS units when they thought it was not working properly because the units had a flashing red light.

DISCUSSION

Global positioning systems are one available resource for providing high-precision movement information for persons.¹ Enormous reductions in cost (units chosen for our studies cost < \$40 each) have helped to make this an accessible technology to use on significant scales to provide quantitative estimates of exposure rates for persons and populations. Such information is not only useful for a fuller understanding of the dynamics of vector-borne pathogens such as dengue, but of the epidemiology of many disease agents. However, even as the technology becomes more accessible, methods for implementing and using location-aware technologies such as GPS for population level studies are limited. This study provides important insights, which although tuned to the nuances of our particular study population, nevertheless will guide other researchers seeking to conduct similar studies elsewhere.

Based on focus group discussions and pilot trials, we concluded that acceptance of GPS units by the population in Iquitos, Peru, would be high. Focus group and pilot study participants expressed concern and questions about proper use and care of the GPS unit, more so than about their own health or convenience. To the best of our knowledge, ours is the first study to identify key questions, concerns, and issues associated to extended GPS unit use raised by potential study participants.

Our results also revealed some differences by gender and sex. Whereas men and women focused on how to carry the GPS unit in a way that would keep the unit safe from thieves, men also expressed concern about their own safety while carrying the unit during the focus groups and in the pilot study. Also, in the young men's groups, it became apparent that some might use the unit incorrectly for fun or not return it. Although we are currently analyzing the data to determine whether there was some incorrect use of the GPS units, only two GPS units were not returned, and the reasons in both cases sounded legitimate (and none were young men). It is possible that handing out documents with the units helped to minimize this behavior.

One issue that did not come up during the focus group discussions, but did come up during the pilot study, was whether the GPS unit was safe to wear during pregnancy. Thus, we had not included any specific information about the safety of the GPS units during pregnancy in our informational pamphlet, but it is additional information that should be provided to participants.

Our findings, although not representative of an entire population, served as a baseline assessment of the types of issues and concerns we might encounter when asking persons in this region to use a GPS unit for 14 days to one month. It is important to point out that focus group participants live in two neighborhoods that have been under surveillance for dengue for many years, and they may be more receptive to participation in a study of this kind because they may have seen or know the dengue surveillance teams and research assistants associated with other dengue studies being carried out. There was high acceptance when GPS units were actually deployed in the pilot study. We have yet to analyze whether people correctly used the GPS units. It should also be noted that selec-

tion of participants for the pilot study was not random and consequently participants selected might have been more willing to cooperate than the general population.

From a series of 15 focus groups in one week, we were able to assess the types of issues and concerns related to GPS use in this particular population. This assessment then enabled us to address these concerns/issues in a short brochure that was handed out with the GPS units when the pilot study was initiated, possibly aiding actual acceptability by addressing a person's questions and concerns from the start. The brochure was in a question-answer format, responded to the main questions posed by the participants in our focus groups, and was given out with a copy of the consent form, which participants signed and kept for their personal records. Both documents addressed the older women's concerns of having some official documentation to show suspicious husbands that proved the GPS unit was for a study, and addressed the young men's suggestion of documenting responsibility for the unit in contract language.

Vector control failures are partly caused by our deficiencies in understanding relationships among interventions, human behavior change, and virus transmission dynamics, difficulties in identifying the most appropriate methods for assessing and responding to risk, and failure to use existing knowledge to make properly informed control decisions.²² Studies examining virus transmission dynamics, including the association between a person's movements and their risk for infection with pathogens such as dengue, are necessary for improving vector control strategies. Global positioning system units are getting smaller, easier to use, and cheaper. These advantages should make them more useful for large-scale studies, and it is likely that they will increasingly be used in longitudinal infectious disease research.¹⁰ However, it is important to take into consideration local sentiment to ensure that the final design is optimized to reduce participant-associated errors and bias. Our study provides important insights for acceptability of long term GPS use by potential study participants. We expect this will improve our use of GPS in longitudinal studies designed to determine how a person's movement across their activity space affects their exposure to dengue virus from bites by infected mosquitoes.

Received August 25, 2009. Accepted for publication November 16, 2009.

Acknowledgments: We thank the focus group and pilot study participants for kindly agreeing to participate in this study; Esther Jennifer Ríos López, Shirley Maribel Guedez Gonzales, and Wilder Carrasco Huaman for their assistance with recruiting, note taking, facilitating focus group discussions, and during the pilot study; Lorena Quiroz Flores for assistance during the pilot study; members of the Peruvian field team (Claudio Rocha, Helvio Astete Vega, Rebeca Carrión, Jorge D'Jalma Vásquez Belchoir, Llerme Armas Pisco, Sadith Jovita Ricopa Manuyama, Maria Edith Juarez Baldera, Acela Rosario Mafaldo Garcia, Jenny Filida Gonzales Sangama, Magali Ochoa Isuiza, Rosa Tamani Babilonia, Karina Chuquipiondo Vásquez, Luz Angélica Galvez Huayllahua, Alan Lozano Frietas, John Elvis Ramirez Paredes, Jimmy Roberto Espinoza Benevides, and Brett Forshey) for their contributions to this study; and Dr. Greg Martin, Dr. John Sanders, and Roxana Lescano (U.S. Naval Medical Research Center Detachment in Lima, Peru) for support.

Financial support: This study was supported by grant R01 AI069341-01 from the U.S. National Institutes of Health/National Institute of Allergy and Infectious Diseases; the Research and Policy in Infectious Disease Dynamics Program of the Science and Technology Directorate, Department of Homeland Security; and the Fogarty International Center, National Institutes of Health.

Disclaimer: The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government.

Disclosure: None of the authors has a financial or personal conflict of interest related to this study. The corresponding author had full access to all data in the study and final responsibility for the decision to submit this publication.

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