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Association Between Physical Activity and Activity Space in Different Farming Seasons Among Rural Lao PDR Residents

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Abstract

Background: Southeast Asia is experiencing a health transition where non-communicable diseases (NCD) are exceeding communicable diseases. Despite NCDs accounting for roughly 60-85% of deaths in the region, many developing Southeast Asian countries are beginning to address the impacts of a physically inactive lifestyle for the first time. Our study aims to bridge this gap by objectively measuring physical activity in rural Lao PDR to reveal the association among physical activity, activity space, and seasonal variation.

Methods: Multiple waves of survey data were collected in Songkhon District, Lao PDR between March 2010 and March 2011. Adults aged between 18 and 65 were recruited (n=48). A portable GPS recorded participants' activity and farmland locations and an accelerometer recorded participants' physical activity level and daily steps for seven consecutive days. Using a directional distribution tool in ArcGIS 10.5, the activity space area of each participant in each wave was calculated. Concurrently, participants recorded time spent on each daytime activity. Linear mixed models with the fixed effects as the observations from different waves and the random effects as individual participants were developed to identify factors associated with areas of activity space and counts of daily steps, respectively.

Results: A total of 48 respondents with half being females were recruited. Walking was found to be the most frequent travel mode. Females were physically less active with smaller activity space and more overweight than their male counterparts. Participants were physically less active during the off-farming seasons.

Conclusions: Findings contribute to the surveillance of risk factors needed to create healthy living environments. Our research is also one of the first to use empirical evidence demonstrating seasonal variations of rural residents' activities in mainland Southeast Asia.

1. Background

Southeast Asia is experiencing a health transition where non-communicable diseases (NCD) are exceeding communicable diseases [1]. Currently, NCDs account for roughly 60–85% of deaths across the region [2], with physical inactivity responsible for approximately 3.2% of the disease burden [3]. One of the main challenges associated with physical inactivity is that it decreases energy expenditure, which increases the epidemic of overweight and obesity [3–5]. A physically inactive lifestyle also leads to higher morbidity rates from cardiovascular disease, ischemic stroke, and metabolic syndrome [3, 6]. Although physical inactivity is a common concern in developed countries [7], many developing countries in Southeast Asia are beginning to note the impacts of a physically inactive lifestyle for the first time [8] as overweight and obesity concerns start to rise [9, 10].

One of the main primary data collection instruments in social, health, and epidemiological research is the survey questionnaire [11]. Using subjective methods such as the International Physical Activity Questionnaire (IPAQ) or Global Physical Activity Questionnaire (GPAQ), considerable surveys have been

conducted to access the physical activity level of the population in developing countries [5, 12, 13]. However, objective measures using pedometers or accelerometers provide a more precise and valid measures of time spent in various physical activities [14–17]. Objective measures are used less often in developing countries due to financial constraints or a lack of expertise managing the technology [18, 19]. Thus, the lack of objective physical activity data from developing countries is a significant barrier in advocating public health interventions that improve physical activity in chronic prevention and control validly and culture-sensitively in different environmental contexts.

Activity space can be quantified through several measures [20–26]. For instance several transportation studies used data from the time-space diary technique; however, this requires a high degree of commitment and collaboration with participants [27, 28], which makes replicating these studies in rural Southeast Asia challenging due to the subsistence lifestyles of its residents. Compared to traditional travel diaries and questionnaires, global positioning system (GPS) tracking devices enhance the ability and reliability of collecting large amounts of trajectory data. As a result, the overall data quality has been greatly improved. At the same time, activity space measured by GPS and step count by accelerometer/pedometer has been increasingly used in physical activity studies to examine the associations between environments and activity [29, 30]. The spaces within which people actually move and are exposed to could explain inter- and intra-personal variations in spatial habits [29]. Hence, understanding activity space could help explain different levels of physical activity.

Environmental factors are expected to be related to physical activity in multiple life domains: leisure/recreation/exercise, occupation, transportation, and household [31]. To identify the association between environment or activity space and physical activity, considerable research has been conducted through a GPS and a geographic information system merged with accelerometer data [32–35]. Although most activity space research is conducted in developed countries, developing countries provide a unique set of challenges that remain understudied [36]. Developing countries in Southeast Asia differ in their built environment, economic activities, seasonal changes, and cultural norms from developed countries in the west [37]. Thus, solutions aimed at increasing physical activity in developed countries, such as parks or sidewalks, may not be effective or directly applicable to developing countries [38].

To this end, our study uses GPS and accelerometer devices to objectively measure physical activity in rural Lao PDR. In doing so, we aim to reveal the association among physical activity, activity space, and seasonal variation in this understudied region. Our results contribute to the surveillance of risk factors needed to create environments that are conducive to healthy living in Southeast Asia and baseline information of activity changes in rural Laos [2].

2. Methods

2.1 Study area

This study was conducted in Songkhon District, Lao PDR (Fig. 1), located near Lahanam, which is situated along the Bang Hiang River, a branch of the Mekong River. The climate is considered tropical

monsoon, where the wet season lasts from April to October. The average seasonal temperature is about 27 °C with an average rainfall of roughly 1,390 mm during the wet season. The dry season starts from November and ends in March with an average seasonal temperature of 23°C and an average precipitation of roughly 73 mm (Savannakhet Provincial Government, unpublished). The village has a total population of 1,091 registered residents, with 628 between 18 and 65 years old as of March 1, 2010 (Village Chief notes). In addition, about 30% of registered adults in the village migrated to Thailand or Vientiane (capital of Lao PDR) for work.

A typical family in Lahanam earns a living by rice cultivating, livestock grazing, fishing, and cloth weaving. Generally, livestock grazing is the work of male adults and weaving is the work of female adults (Author's field note in 2010, unpublished). However, both female and male adults engage in fishing year-round (Author's field note in 2010, unpublished). Consistent with other regions of Lao PDR, rice cultivation is the major subsistence of local residents (Author's field note in 2010, unpublished).

Our study area has roughly four seasons: wet farming, wet off-farming, dry farming, and dry off-farming. Two types of rice cultivation are carried out in the wet and dry seasons. The wet season rice cultivation, which is rain-fed, starts from May and is harvested in October [39]. The dry season cultivation is carried out in sections of the rice paddy with irrigation from December to April. The drastic differences in precipitation between wet and dry seasons have a direct impact on individual activities. To that end, our survey is predicated on the four seasons based around Lahanam's farming activities.

2.2 Data collection

To capture the seasonal activity changes of local residents, multiple waves of surveys were carried out in Lahanam from March 2010 to March 2011. In each wave, two devices were used to collect data for each participant for seven consecutive days. The first, a portable GPS device (M241, Holux Technology, Inc.), recorded activity and farmland location of participants. The second, an accelerometer instrument (Lifecorder EX, Suzuken Ltd.), measured the participant's physical activity level and steps. Recording was made every twelve seconds for the GPS and two minutes for the accelerometer. Concurrently, a self-reported log by each participant detailed the time spent on each activity from 6 am to 6 pm. The body weight and height of each participant was measured by the researchers. GPS data were validated by the accelerometer and, if no record existed in the accelerometer, we excluded the data.

The first wave of data collection was conducted in March 2010 to test the GPS devices battery and whether the device shell was waterproof in the study area. Wave one consisted of 20 participants, 10 males, and 10 females, with each participant aged between 18 and 65 years. From Wave 2 to Wave 5, about 30 participants aged between 18 and 65 were recruited, respectively. Waves 2 to 5 covered four different farming seasons, namely wet farming season (Wave 2: June 2010), wet off-farming season (Wave 3: September 2010), dry farming season (Wave 4: December 2010) and dry off-farming season (Wave 5: March 2011). Twenty thousand Lao kips (USD $2.50) was given to each participant who completed one wave, with a total of 100,000 Lao kips (USD $12.5) given to participants who completed all five survey waves. Only Wave 2 to Wave 5 were included in the further analyses.

Neighborhood built environment attributes were derived from google maps and QuickBird satellite image which was taken on January 9, 2008. Euclidean distances from participant's home to different types of land uses such as paddy, the health center, the primary school, the middle school, the local market, the temple, and the mini shop in the village were measured in order to identify different destinations where residents frequently visit.

2.3 Creating activity space

The most common method to operationalize activity space is the standard deviation ellipse (SDE) that measures the directional distribution of a series of GPS points or the "densest" areas where most of the individual mobility occurs [40]. The SDE is usually centered at an individual's home [41] and extended two standard deviations to cover 95% of the observed activity locations [42]. This study uses an SDE to represent the participant's activity space [42]. Because the SDE approach helps to assess the direction and general shape of a person's travel area without introducing potential errors using geographically distant points or a road network that is not reliable.

For each participant in each wave, activity space was delineated as an ellipse centered at the home and extended to two standard deviations of the observed activity locations that were recorded by the GPS device worn by each participant (see Fig. 2 for a participant's one-day activity). The area of each activity space was calculated using a directional distribution tool in ArcGIS 10.5. The tool summarized spatial characteristics and created an SDE polygon as the output activity space. A 1-, 2-, and 3 - SDE polygons were computed to cover 68%, 95%, and 99% of the input features, respectively. Considering that a 1-SDE covers 68% of activity points, several participants' activity space may not be constructed accurately using the 1-SDE approach. Conversely, using a 3-SDE may include outliers that distort the shape of the ellipse and introduce concerns similar to the minimum convex polygon approach which could result in measuring the extreme extent of travel and capture large geographic areas that are not visited by an individual. Therefore, our study used a 2-SDE polygon to delineate activity space in line with previous research [42].

2.4 Statistical Analysis

Bivariate analysis of variables derived from the daytime activity log, and distance measures of land use were carried out with areas of activity space and counts of daily steps. Furthermore, ANOVA tests controlling for different waves were conducted for the two dependent variables by gender, and the self-reported time for different activities by gender by wave, respectively. Linear mixed models with the fixed effects as the observations from different waves and the random effects as individual participants were developed to identify factors associated with areas of activity space and counts of daily steps, respectively.

3. Results

3.1 Descriptive statistics

A total of 48 participants aged between 19 and 57 years, which count for 10% of the total adult residents living in the village, took part in the four waves of the study. Half of the participants (24) were females. The average age of the participants was 36. The average BMI of participants was 22.7 kg/m^2. One-fourth of the female participants were overweight with BMIs more than 25 kg/m^2, and one eighth of male participants are overweight. On average, 31 participants took part in each wave. Only six participants finished all four waves while 22 and 13 participants did three and two waves of four waves, respectively, and seven participants one wave only.

Self-report logs were summarized as follows. For outdoor activities, the participants spent on average 2.1 hours on cultivating rice, 0.2 hours fishing, 1.0 hours grazing livestock, 0.2 hours hunting & gathering. As for indoor activities, 1.1 hours weaving, and 2.2 hours doing housework. And about 5.1 hours were spent for other activities such as chatting with other people, eating and drinking, and resting.

Among all participants, two participants did not have farmland. The Euclidean distances of the remaining participants' farmland to their homes ranged between 65 meters and 4808 meters, with an average of 1,729 meters. The average distances from participant's home to health center, primary school, middle school, local market, temple, and mini shop are 532 meters, 588 meters, 464 meters, 465 meters, 337 meters, and 109 meters, respectively. Table 1 summarizes participant's individual characteristics, daytime activity log, and distance from participant's home to different destinations in the village.

The average sizes of the activity space were 29.6km^2, 16.9km^2, 9.5km^2, and 37.9 km^2 for wet farming season (Wave 2), wet off-farming season (Wave 3), dry farming season (Wave 4), and dry off-farming season (Wave 5), respectively. The average daily steps for Waves 2, 3, 4, and 5 are 16,861, 13,205, 14,736, and 13,297, respectively. There were three female participants with average daily steps fewer than 10,000 steps – a conventional threshold for inactive lifestyle [43, 44] – in Wave 2, five females and two males with average daily steps fewer than 10,000 steps in Wave 3, and four females in Wave 4 and six females in Wave 5 with average daily steps fewer than 10,000. Table 2 summarizes the size of activity space and counts of daily steps by gender for each wave.

3.2 Bivariate Analysis

To compare activity space and total steps between female and male, natural logarithm transformation was carried out for the area of each activity space and each participant's counts of daily steps. Table 3 summarizes the natural logarithm transformation of areas of activity space and total counts of steps by wave and by gender and ANOVA test results. ANOVA tests showed that the area of activity space is significantly different between females and males for Waves 2 and 5. The counts of daily steps are significantly different between females and males throughout all waves. ANOVA tests were also conducted for self-reported time spent on different activities by gender for each wave. Table 4 summarizes the ANOVA results. Male participants spent significantly more time on outdoor activities than their female counterparts in all four waves. The former spent more time than the latter for other activities such as chatting with other people, eating and drinking, and resting in Waves 2 and 3. Meanwhile, female

participants spent significantly more time on indoor activities such as weaving and doing housework in all four waves.

Table 5 summarizes results of the Pearson's correlation analysis. The area of activity space and counts of daily steps were positively significantly correlated. In addition, time spent on indoor activities such as weaving and doing housework was negatively significantly associated with daily steps and activity space. Time spent on outdoor activities such as cultivating rice, fishing, livestock grazing, and hunting and gathering was positively significantly associated with daily steps and activity space.

3.3. Regression model results

Based on the bivariate analysis results, two linear mixed models were developed for daily steps and activity space, respectively. The fixed effects included observations of participant's characteristics such as age and gender, time spent on outdoor activities, and distance from home to participant's paddy field. Wave information was also added into the model as a category variable using Wave 5 as the reference. The individual participants were included as the random effect to control for variations of individual participants. Table 6 summarizes the linear mixed model results. Females were found to have significantly fewer steps and smaller activity space compared with those of their male counterparts. Age was negatively significantly associated with activity space only. As expected, time spent on outdoor activities was positively significantly associated with daily steps and activity space. Compared with Wave 5, participants in Waves 2 have significantly more daily steps, and participants in Wave 4 showed a positive marginal significance. No significant difference was found for activity space among different waves.

4. Discussion

Our findings showed that participants' daily steps and activity space were positively significantly associated with each other. In other words, with more daily steps, a participant's activity space increased. Despite some study participants owning motorcycles, the substandard road conditions required many participants to walk while performing daily activities. Examples include rice cultivating, paddy fishing, livestock grazing, and individual hunting and gathering. These activities, measured by step count, are also consistent with our field observations. Taken together, these results imply that our study participants were more likely to travel on foot for their daily activities. This is quite different from studies in the U.S. and China where driving and car ownership are associated with larger activity space [40, 45]. These findings underscore the importance of identifying place-based solutions to public health challenges [38], especially in developing Southeast Asian countries.

Although study participants traveled mostly by foot, female participants were found to have significantly fewer daily steps and smaller activity spaces than those of their male counterparts. This finding is similar to the findings in other countries where an increasing gender gap of physical activity has been observed [5, 46-48]. Our study also found that one-fourth of the female participants and one-eighth of male

participants were overweight with BMIs greater than 25 kg/m^2. Despite finding lower overweight rates among male participants, these results were consistent with a WHO STEP [49] study in the capital of Lao PDR. Our finding suggested that analyses of activity space would be able to evaluate risks of obesity in paddy farming communities.

The division of labor in our study area may be the core issue of this finding. For instance, male participants were found to spend much more time on outdoor activities including rice cultivating, fishing, and livestock grazing. Female participants, on the other hand, spent the majority of their time on indoor activities such as weaving and housework. Our findings are consistent with the previous studies on labor division in Lao PDR [50]. Surprisingly, despite walking being the most frequent travel mode in the study area, there are still a few participants with daily steps fewer than 10,000, an important indicator for an active lifestyle [43, 44]. One explanation, as shown in Table 4, is that both male and female participants spent more than one-third of their day-time on sedentary or low-level physical activities such as chatting, resting, drinking or eating. However, females spent more time on low-level physical activity indoors such as weaving and housework. Therefore, with gyms, parks, and other public spaces not readily available in the region, it is difficult for rural Southeast Asians to increase physical activity in a subsistence lifestyle. Thus, future studies and intervention programs could focus on how to incorporate physical activities into leisure time to promote healthier lifestyles in particular, increasing physical activities for rural Southeast Asian females in their leisure time, as males tend to receive more physical activity from their work in the region.

When comparing physical activities of different farming seasons, participants in Wave 2 (wet farming season) and Wave 4 (dry farming season) were found to have more daily steps than those participants in Wave 5 (dry off-farming season). This finding indicated that physical activity levels of residents in the region are strongly impacted by farming or not. This evidence demonstrates that seasonal variation does impact rural resident activities in mainland Southeast Asia. Thus, future interventions aimed at increasing physical activity should prioritize the off-farming season where subsistence work is reduced and residents are less physically active.

The study area is also where a high prevalence of Human Liver Fluke (HLF) was detected [51-53]. Given that human movement through space and time has a direct impact on disease transmission, larger activity spaces may be associated with higher chances of open defecation, which is a major contributor to high prevalence rates of HLF in the region [54, 55]. In our study, we found that male participants have a significantly larger activity space and spend more time outdoors. This combination indicates that males might disproportionately contribute to the transmission of HLF in the region. This information is crucial to identify common places where transmission might occur. With the patterns of contact between HLF and hosts varying, future studies should also identify male open defecation locations so that effective and efficient interventions could be devised to target key places of transmission between humans and the environment. Thus, the potential to leverage public health programs by allowing limited resources to be targeted to the most important locations. This helps ease the burden of local public health departments

in developing countries that face the double burden challenge of communicable and non-communicable diseases on the rise.

Our study also has a number of limitations. For instance, the sample size is relatively small. Moreover, our study only collected data for one year. Longitudinal studies with historical data and larger sample sizes would bring richer insights into the health transition of developing countries. Our sample represented “active” farmers rather than the “inactive” industrialized urban people, who are more at risk of obesity, in Southeast Asia. However, our results will be a useful baseline data to know physical activity and activity space of farmers in Southeast Asia and to track changes in future and thus will be followed by further studies.

5. Conclusion

Our study is one of the first to objectively measure activity space and physical activity to assess the impact of farming seasons in rural Southeast Asia. Physical activity levels are strongly impacted by whether residents farm or not in the region. Integrating GPS tracking and accelerometer data to depict an activity space where individuals travel and how much time they spend on different daily activities could allow for advances in assessing the health risk factors of both communicable and non-communicable diseases. Understanding daily travel activities in this way may contribute to effective intervention programs needed to create healthy living environments in Southeast Asia.

Abbreviations

NCD: Non-Communicable Disease;

GPS: Global Poisoning System

IPAQ: International Physical Activity Questionnaire

GPAQ: Global Physical Activity Questionnaire

SDE: Standard Deviation Ellipse

HLF: Human Liver Fluke

Declarations

Ethics approval and consent to participate

Ethics approval was granted by the Ethics Review Committee at the Research Institute for Humanity and Nature (Research Ethics Review Committee Reference Number: No. RIHN-2007-03). Written informed consent is obtained from all participants prior to data collection.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests.

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Author’s Contributions

KM and HWJ acquired research grants. HWJ and KM designed the study. HWJ conducted the field survey, and prepared the datasets. HWJ, LL, and DY conducted the analysis and drafted the manuscript. HWJ, LL, DY and KM have read and approved the final version of the manuscript.

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Tables

Table 1
Summary of participant's individual characteristics, daytime activity log, and distance from participant's home to different destinations in the village

Category	Item		Value
Individual characteristics	Age		Mean = 36.2; SD = 9.6
	Gender		Female: 24 Persons Male: 24 persons
	Body weight (kg)		Mean = 55.2; SD = 10.0
	Body height (cm)		Mean = 155.7; SD = 7.7
	BMI (kg/m^2)		Mean = 22.7; SD = 3.0
	Overweight and obesity (BMI > = 25 kg/m^2)		Female: 6 Persons (25%)
			Male: 3 Persons (12.5%)
Daytime activity log (hours)	Time spent for outdoor activities	Rice cultivating	Mean = 2.1; SD = 2.2
		Fishing	Mean = 0.2; SD = 0.7
		Livestock grazing	Mean = 1.0; SD = 1.3
		Hunting & Gathering	Mean = 0.2; SD = 0.4
	Time spent for indoor activates	Weaving	Mean = 1.1; SD = 1.9
		Housework	Mean = 2.2; SD = 2.0

[1] Two participants who did not have paddy fields were excluded from the calculation

Category	Item		Value
	Time spent for other activities	Chatting with other people, eating and drinking, and resting	Mean = 5.1; SD = 1.6
Distance from participant's home to different destinations (meter)	Paddy field [1]		Mean = 1729; SD = 1105
	Health center		Mean = 532; SD = 220
	Primary school		Mean = 588; SD = 222
	Middle school		Mean = 464; SD = 222
	Local market		Mean = 465; SD = 216
	Temple		Mean = 337; SD = 106
	Mini shop		Mean = 109; SD = 194

[1] Two participants who did not have paddy fields were excluded from the calculation

Table 2
Activity Space and Daily Steps by Gender and by Wave

Wave		**Sex**	**N of Persons**	**Steps (per day)**		**Activity Area (km^2)**	
				Mean	*SD*	*Mean*	*SD*
Wave 2 wet farming	Jun 2010	Female	15	12,919	2,923	6.9	8.8
		Male	15	20,802	5,818	52.3	125.8
		summary	30	16,861	6,044	29.6	90.6
Wave 3 wet off-farming	Sep 2010	Female	16	10,950	3,527	8.6	21.1
		Male	16	15,459	5,254	25.2	42.0
		summary	32	13,205	4,962	16.9	33.7
Wave 4 dry farming	Dec 2010	Female	19	12,386	3,086	6.4	6.4
		Male	13	18,170	3,907	14.1	10.1
		summary	32	14,736	4,446	9.5	8.8
Wave 5 dry off-farming	Mar 2011	Female	15	11,211	4,141	16.0	30.9
		Male	14	15,532	4,287	61.4	155.8
		summary	29	13,297	4,683	37.9	110.8

Table 3
ANOVA Result of Activity Space and Total Steps by Gender and by Wave

			Female		**Male**		**ANOVA**
			Mean	*SD*	*Mean*	*SD*	p-value
Wave 2	Jun 2010	LN (2SD SQM)[1]	0.75	2.03	2.33	1.75	**0.030**
		LN (daily steps)[2]	9.44	0.23	9.90	0.30	**0.001**
Wave 3	Sep 2010	LN (2SD SQM)	-0.08	2.16	1.42	2.21	*0.062*
		LN (daily steps)	9.24	0.38	9.58	0.42	**0.026**
Wave 4	Dec 2010	LN (2SD SQM)	0.66	2.22	1.97	1.82	*0.090*
		LN (daily steps)	9.40	0.25	9.78	0.24	**0.001**
Wave 5	Mar 2011	LN (2SD SQM)	-0.19	2.95	2.33	1.69	**0.010**
		LN (daily steps)	9.26	0.38	9.62	0.27	**0.007**

[1] LN (2SD SQM): natural log transformation of activity space

[2] LN (daily steps): natural log transformation of counts of daily steps

Table 4
ANOVA Results for Self-Reported Time for Different Activities between 6 am and 6 pm by Gender by Wave (Hours/day)

		Female		**Male**		**ANOVA**
		Mean	*SD*	*Mean*	*SD*	p-value
Wave 2	Outdoor activities	3.4	2.3	6.0	1.9	**0.002**
	Indoor activities	4.2	2.3	0.5	0.8	**0.001**
	Other activities	4.4	1.0	5.5	1.6	**0.027**
Wave 3	Outdoor activities	1.6	1.4	4.8	2.1	**0.001**
	Indoor activities	5.8	2.0	0.6	0.8	**0.001**
	Other activities	4.6	1.3	6.6	2.1	**0.003**
Wave 4	Outdoor activities	2.7	2.1	4.9	2.5	**0.013**
	Indoor activities	4.5	2.4	1.7	1.7	**0.001**
	Other activities	4.7	1.0	5.4	1.6	0.149
Wave 5	Outdoor activities	1.7	1.2	4.2	2.3	**0.001**
	Indoor activities	5.3	2.1	2.9	2.2	**0.005**
	Other activities	5.0	1.5	5.0	1.5	0.953

Table 5
Pearson Correlation Results

	Daily steps (natural log transformed)	**Activity space (natural log transformed)**
Activity space (natural log transformed)	0.539 ***	
Time spent on indoor activities (weaving and doing housework)	-0.518 ***	-0.395 ***
Time spent on outdoor activities (fishing, livestock grazing, and hunting and gathering)	0.353 ***	0.282 ***
Time spent on other activities (chatting with others, eating and drinking, and resting)	-0.137	0.147
Time spent on rice cultivating	0.490 ***	0.186 **
Distance from home to paddy	-0.030	0.060

[1] ***: p-value < 0.01 **: p-value < 0.05

Table 6
Linear Mixed Model Results (Fixed effect) - Daily Steps and Activity Space

	Daily steps (natural log-transformed)		**Activity space (natural log-transformed)**	
	B	P-value	B	P-value
(Constant)	9.262	0.000	2.104	**0.015**
Gender (male vs. female)	0.172	**0.009**	1.368	**0.004**
Age	-0.003	0.306	-0.069	**0.002**
Outdoor[1] activity time	0.081	**0.000**	0.194	**0.052**
Distance[2] from home to paddy (km)	-0.043	0.092	0.130	0.455
Wave 2	0.142	**0.030**	0.295	0.587
Wave 3	-0.003	0.962	-0.443	0.398
Wave 4	0.113	0.054	0.068	0.894
Wave 5[3]	0.000			

[1] Time spent on outdoor activities such as rice cultivating, fishing, livestock grazing, and hunting and gathering

[2] Distance from home to paddy field in km

[3] Reference category

Figures

Fig. 1

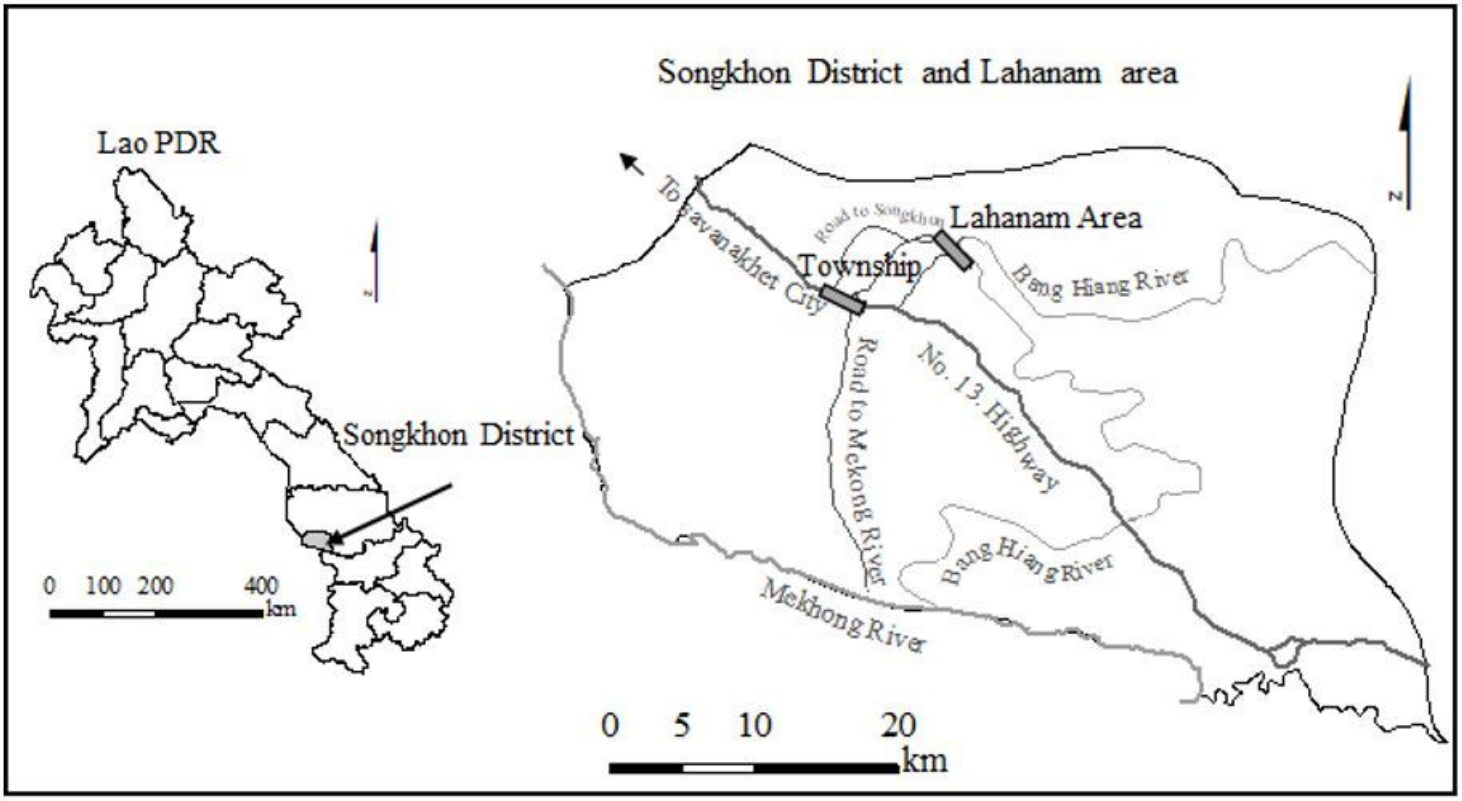


Figure 1

Lahanam area in Songkhon District, Lao PDR. The target village, located inside the rectangular shape labeled as Lahanam Area on the map, is situated along the west bank of the Bang Hiang River (This map was created by the authors).

Fig. 2

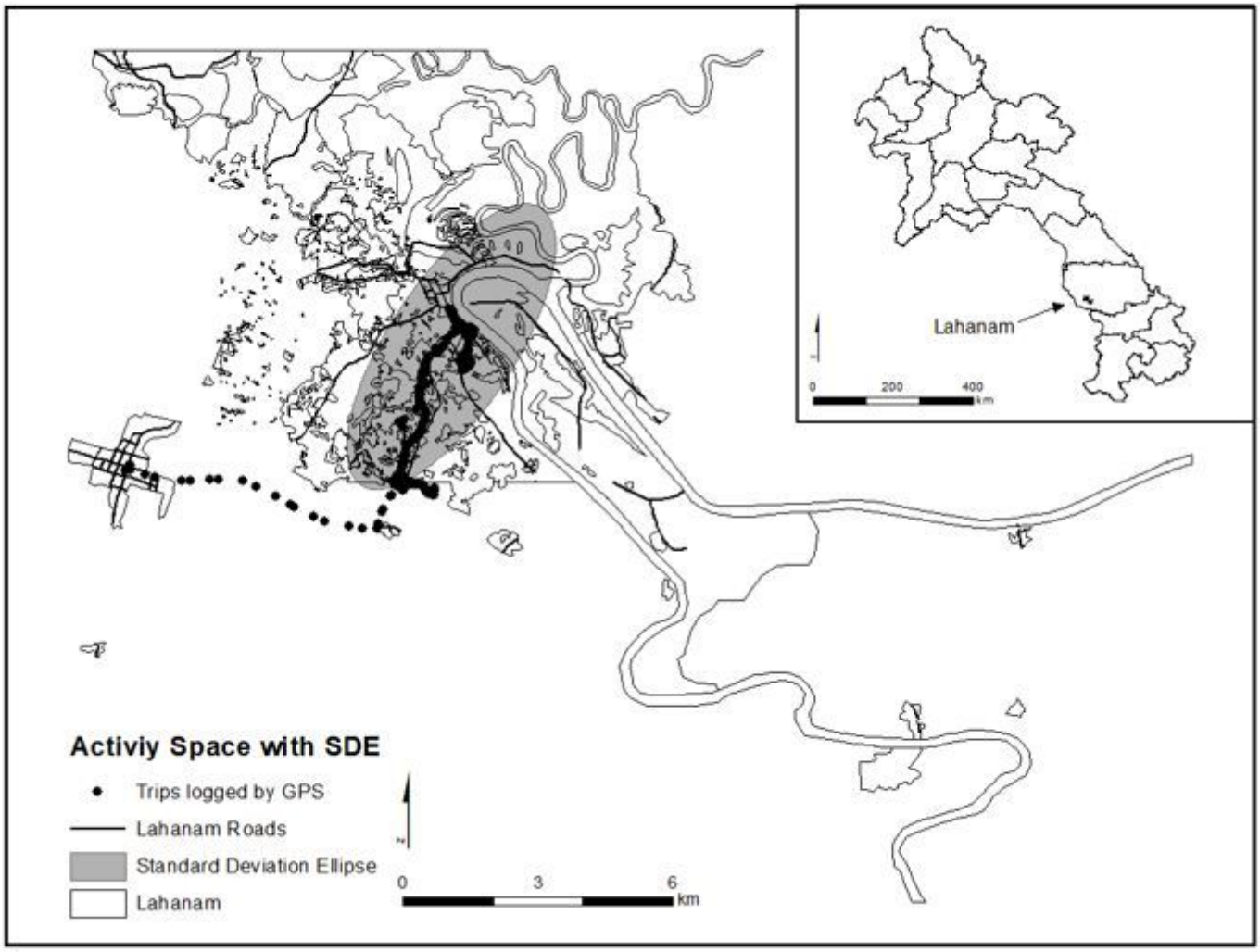


Figure 2

Example of a participant's daily activity movement with a 2-standard deviation ellipse representing the participant's activity space shaded in gray (This map was created by the authors).