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Adolescent Travel Patterns: Pilot Data Indicating Distance from Home Varies by Time of Day and Day of Week

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See Editorial p. 327

Abstract We conducted a pilot study using new technology to track adolescent "place." Using Global Positioning System (GPS)–enabled cell phones, we recruited and tracked 15 female adolescents for a 1-week period. Distance away from home was greatest in the evenings on weekends or holidays. The greatest percentage of time spent more than 1 kilometer away from home was also during these times. Such GPS technology holds promise for future adolescent health research in allowing more specific and dynamic measurement of where adolescents spend time.

Keywords: Adolescents; Context; Neighborhood; Time of day; Day of week; Travel; Corresponding

Adolescents nonrandomly choose times of health-related behaviors. For example, substance use is more likely to occur from 3–6 PM on school days [1] and sexual activity to occur more frequently during the evening hours on weekends and vacation days [2]. Social and physical context (place) is also important. For example adult supervision is associated with decreased risk behaviors [3]. In addition an adolescent's neighborhood characteristics are associated with health-related behaviors [4–7]. Studies of context of adolescent health-related behaviors, however, are restricted to static assessments using an individual's residential address and an arbitrary area surrounding that point to define contextual exposure. Few studies account for both time and space in considering an adolescent's health-related behaviors, and those that have concentrate on location types [3], rather than travel patterns, which enable evaluation of such aspects as distance from home.

Technology is now available to measure real-time location using Global Positioning System (GPS) devices. Emerging research using such technology includes assessing pesticide exposure in children of migrant farm workers [8] and characterizing environmental factors that may influence child physical activity (more information is available at: http://www.casa.ucl.ac.uk/capableproject/). GPS devices could be used to determine where and when adolescents spend time to better specify context and more accurately study how it influences health. We performed a pilot feasibility study to demonstrate the use of this technology in studying adolescent health-related behaviors and to demonstrate patterns and variability of activity by time of day and day of week.

Methods

Sample

We recruited 15 female adolescents to carry GPS-enabled cell phones for 1 week. The inclusion criteria were: (1) female

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gender, (2) age 14–17 years, (3) willingness and ability to travel at least 3 blocks away from home daily, (4) ability to carry a phone at all times for 7 days, and (5) English speaking. We included a travel requirement to differentiate malfunctioning hardware or software from truly limited mobility. Subjects were recruited using a practice-based research network in a Midwest metropolitan area. The study took place from October to early December 2006. The protocol was approved by the university's institutional review board. Subjects gave informed consent, and parents provided written permission for participation. We disclosed to participants that we were tracking their locations and that all GPS data and corresponding maps would remain confidential between researchers and participants. Five participants were ineligible or refused to participate: two were ineligible because of language; two refused because of time; and one refused with no reason given.

Procedures

A research assistant met with the adolescent, oriented her to the phone, and reviewed study requests. Participants carried Blackberry 7520 cell phones with integrated assisted GPS. A more complete description of GPS data acquisition modalities that may be used to study pedestrian spatial behavior is available elsewhere [9].

Measures

The GPS devices were programmed to transmit timestamps, device identifications, and geographic coordinates every 5 minutes to a study database residing on a secure server.

A "weekday" was defined as Monday through Thursday and Friday until 3 PM. A "weekend" included remaining times and holidays.

We calculated each point's distance from the participant's home address. A 1-kilometer distance from home was used as a threshold to represent approximately a 10-minute walk. This distance was used as a threshold in other studies examining contextual exposure using residential address data [10].

Imputation

When more than 5 minutes but less than 1 hour elapsed between data points, we imputed interim 5-minute time points. If two temporally adjacent points bounding a period of missing data were within 30 meters (the distance used to determine the two points were in the same or similar location), we assigned the missing GPS data point to the earlier point. For data points more than 30 meters apart, we made imputations in two ways. In one case, we used the point that was closer to home, and in another we used the point that was further from home. Because results were very similar for these two approaches, we present the data for using the closer-to-home imputed point. We performed all analyses by varying the time lapse cut-off for imputation (1–24 hours) and found similar results.

Analysis

GPS data from the secure server were imported into ArcGIS 9 (Environmental Systems Research Institute [ESRI], Redlands, CA), where corresponding recorded points were visualized, missing data were imputed, and distances from home were calculated. We tabulated distance from home and percent of time more than 1 kilometer away from home with time of day using Stata/SE 9 (Statacorp, College Station, TX). All analyses accounted for clustered within-person observations. One subject was excluded from this analysis because the time period encompassed an out-of-town vacation and thus did not represent her typical travel patterns.

Results

Of the data points, 83% of points were within 5–6 minutes following the previous point. Approximately 2% of points had more than a 1-hour lapse and 0.5% more than a 4-hour lapse. In total 71% of the possible 5-minute time points were occupied with GPS data transmitted directly from the cell phone, and 11% of the remaining missing data were between two known points 30 meters or less apart.

The adolescents in this study traveled further from home in the evenings and early mornings on weekend days, with mean distances of up to 28 kilometers (Figure 1). Otherwise they traveled to locations averaging 3.5–8.9 kilometers away from home.

The percentage time spent more than 1 kilometer from home (Figure 2) was greatest on weekends during evening and early morning hours. For weekdays there was less variability in time spent more than 1 kilometer from home. Overall, participants spent one third of their time more than 1 kilometer from home (25% if school time, i.e., 8:00 AM to 2:59 PM on weekdays, is excluded).

Discussion

The data indicate that cell phones can be used to track space/time paths and destinations of adolescent study sub-

	mean	*sd*
Weekday		
12:00am - 7:59am	**4.5**	*15.7*
8:00am - 2:59pm	**3.8**	*12.8*
3:00pm - 5:59pm	**5.6**	*14.9*
6:00pm - 11:59pm	**5.1**	*14.7*
Weekend/Holiday		
12:00am - 7:59am	**13.9**	*26.2*
8:00am - 2:59pm	**8.9**	*22.1*
3:00pm - 5:59pm	**3.5**	*9.2*
6:00pm - 11:59pm	**28.1**	*31.5*

Figure 1. Distance (km) away from home by time of day.

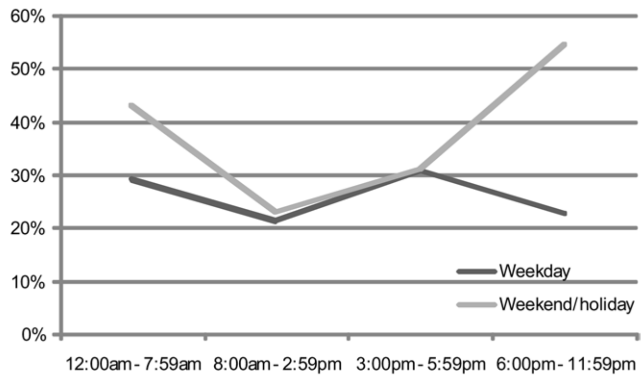

Figure 2. Percent time spent >1 km away from home.

jects. It is notable that all phones were kept operational and returned in good condition. The participants' travel patterns were variable but showed clear differences between weekdays and weekends. Distance from home and percentage of time spent more than 1 kilometer away from home was greater on the weekends and holidays than on weekdays, particularly in the evening and early morning.

Data suggest that individuals have variable travel patterns extending beyond their immediate neighborhoods. In cases in which they stay primarily within their neighborhoods, this technology has the capacity to show more detailed information of where they spend time, both inside and outside of their neighborhoods.

The analysis of GPS data should be interpreted with caution, because this study was done primarily for feasibility purposes. Data were transmitted with less consistency (fewer data points) at the beginning of the study than at the end, because we were trouble-shooting technical issues with the phones and GPS data transmission process. There is no indication, based on debriefing interviews, that data were otherwise selectively collected (i.e., participants reported that the phone was *not* more likely to be turned off at certain times of the day or when the participant was traveling somewhere she did not want to be "tracked"). In addition we have no data on school location to calculate distance from school during times when school was in session. Of note several of the participants had either dropped out of school or were not attending school during the study period.

All in all these data indicate that GPS-enabled cell phones can be used to gain a better understanding of where adolescents spend time. Time spent away from home and the immediate surrounding area suggests that the traditional use of residential address for contextual exposure may be inadequate for adolescents. Residential address indicates only one of many relevant contexts where adolescents may choose to spend time. Furthermore this technology allows analysis of destinations, paths, and overall activity patterns by operationalizing the concept of *dynamic* contextual exposure. These data in combination with reports on health-related behaviors and contextual characteristics could contribute to a greater understanding of how and why context contributes to health-related outcomes among adolescents.

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