A NEW APPROACH TO IDENTIFY THE LOCATION AND INTENSITY OF PHYSICAL ACTIVITY IN URBAN AREAS: THE USE OF ACCELEROMETER AND GLOBAL POSITIONING SYSTEMS DATA

GOZDE EKSIOGLU CETINTAHRA[1], EBRU CUBUKCU[2]

ABSTRACT

Recent studies showed that physical inactivity leads to chronic diseases and death. Various practices and policies, which have been discussed to promote physical activity, require information about the barriers of physical activity. Research focused on not only biological, social and psychological characteristics but also physical environment characteristics as barriers of physical activity. Yet, which and how physical environmental characteristics affect individual’s physical activity is still unknown (as research on physical environment characteristics produced contradictory findings). Methodological differences may have led to such contradictory findings. Subjective and objective methods have been used to identify people’s physical activity levels. Subjective methods (such as self-report, face to face interviews and telephone surveys) tend to produce semi-reliable data which is based on personal declaration. Objective observation methods, such as physical activity monitors, have been acknowledged to produce more reliable data. Accelerometer, a kind of physical activity monitor, sorts and stores intensity of physical activity (sedentary, light, moderate and vigorous physical activity parameters) with reference to date, time and activity counts. Although, accelerometers fail to reveal information about the location of the activity, combined data of accelerometer and Global Positioning Systems (GPS) provides this information. The present study aims to introduce a new methodology to map the location where children are active and inactive. 51 children (9-12 years old), who were attending sportive activities in a private Sport School in Izmir, volunteered to participate. Information about the intensity of their physical activity was collected via accelerometer (Actigraph wGT3X-BT) and information about where their activities took place was collected via GPS (Qstarz Travel Recorder XT). Participants were asked to wear the devices for 7 days (5 week days, 2 weekend days). Accelerometer data analyzed with ActiLife software, and the GPS data analyzed with Qstarz Data Viewer software. The data were matched and combined via ArcGIS. Based on the combined data participants’ physical activity intensities were mapped.

Keywords : Physical activity, accelerometer, global positioning systems.

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[1] Res. Asst. Dokuz Eylul University, Department of City and Regional Planning, IZMIR

[2] Prof. Dr. Dokuz Eylul University, Department of City and Regional Planning, IZMIR

1. INTRODUCTION

World Health Organization announced that childhood obesity is a global public health problem (WHO, 2014) that could penetrate to next generations. Childhood obesity causes chronic diseases and death (Stettler et al., 2002). Sixty minutes of moderate to vigorous physical activity at least 3 days per week (USDHHS, 2008) is recommended to prevent obesity. However, research showed that high proportion of population could not achieve this recommended amount of physical activity in their daily life (CDC, 2002). Therefore, identifying the barriers of physical activity is necessary.

One barrier that prevents a child to be physically active is physical environmental characteristics (Burdette & Whitaker, 2005; Ewing et al. 2003; Frank et al. 2004; French et al. 2001; Hill et al. 2003; Lopez, 2004; Saelens et al. 2002; Saelens et al. 2003). *Presence of mixed land use in the neighborhood* (Dunton et al. 2013), *presence of urban parks, playgrounds, and sports clubs in the neighborhood* (Brodersen et al. 2005; Coombes et al. 2013; Dunton et al. 2013; Mackett et al. 2007; Quigg et al. 2010; Timperio et al. 2004; Tucker et al. 2009; Van Sluijs et al. 2011; Wheeler et al. 2010;), *distances between the house and various amenities* (CDC, 2002; Hume et al. 2007; Kemperman & Timmermans, 2011), *the level of traffic safety on the neighborhood streets* (Hume et al. 2009; Timperio et al. 2004; Trapp, et al., 2012; Ziviani et al. 2004) and *presence of active trasportation opportunities in the neighbourhood* (Cooper et al. 2005; Tomson et al. 2003; Ford et al. 2007; Davison et al. 2008; Loucaides & Jago, 2008; Southward et al. 2012) have been listed as the physical environmental characteristics that may effect the level of children's physical activity. Although majority of research showed a significant effect of those variables on physical activity, few did not. This contradictory findings may stem from methodological differences in measuring physical activity. Thus it is necessary to discuss the potential advantages and disadvantages of various measures of physical activity. Recent studies investigated children's physical activity intensity via either subjective or objective measures. This study used both measures to compare advantages and disadvantages.

Moreover, majority of research focused on the physical environmental characteristics in the close vicinity of the child’s house (or the neighbourhood). However, common knowledge suggests that a child could be active beyond the neighborhood unit. In paralel, Yin et al. (2013) highlighted the fact that children's physical activity cannot be limited to close vicinity around their houses or well defined bordered areas. Given that, this study aims to discuss a methodology to map the locations where children are active and inactive. Such methodological improvements would pave the way to analyze the physical environmental barriers of physical activity not only in well defined bordered areas but also in the whole city.

2. MEASURES OF PHYSICAL ACTIVITY

2.1. Subjective Measures of Physical Activity Intensity and Location

Subjective measures of physical activity intensity and location refers to self-reporting techniques such as the use of diaries and surveys. These methods are low cost and easy to apply to large populations in a short amount of time. Various structured survey forms have been developed and widely used. For example, the survey form developed by Active Living Research (a program of the Robert Wood Johnson Foundation) and titled as "Active Where? Parent-Child Survey" collects information about the children's physical activity intensities and locations. A similar survey form is used in this study to derive information about children's tendency to be active or inactive and where do they tend to be active (indoors or outdoors) (Table 1). As children may reveal inaccurate and unreliable information due to misunderstanding, this survey form is filled by parents. Yet, as all other survey forms, data derived via such reporting techniques are not free from systematic or random errors. Subjective measures usually involve recall bias (Ward, et al. 2005).

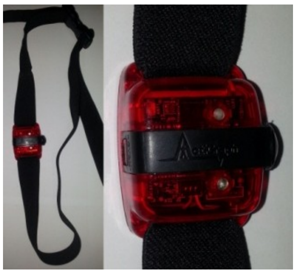
Table 1. Subjective measures of children's physical activity

Survey question type	Question	Evaluation
Children's activity behavior	Does your child attend to a sport club regularly? Does your child involved in unorganized sportive activities regularly? Does your child attend to other activities regularly?	Yes, No
Children's sedentary behaviors	Does your child interact with electronic instruments often (TV, VCD/DVD player, PC/tablet, etc)?	Yes, No
Children's activity location	Generally my child is active at home. Generally my child is active in closed areas except home. Generally my child is active in opened areas.	Agreed, Uncertain, Disagreed

2.2. Objective Measures of Physical Activity Intensity and Location

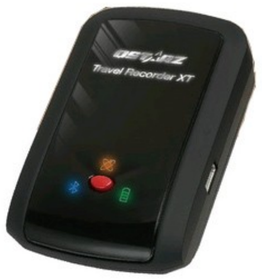
Activity monitors are claimed to produce more reliable data to understand the intensity of physical activity (Ward, et al. 2005). There are 2 kinds of activity monitors: (1) pedometer and (2) accelerometer. Pedometers are sensitive only on step counts. Thus, pedometers could provide information on distances, but not on exact location of routes. Accelerometers can sort and store the intensity of physical activity (sedentary, light, moderate and vigorous physical activity parameters) with reference to date, time and activity counts. Compared to pedometers, accelerometer data collects information about all kinds of activities (not only walking or running).

Figure 1. Accelerometer: Actigraph wGT3X-BT



Similar to pedometers, sole use of accelerometers fail to reveal information about the location of the physical activity. In the last decade, researchers began to use accelerometer with global positioning system (GPS) devices. GPS is a kind of global navigation system and provides information about the exact location of any place on the Earth based on satellite data (Kreen et al. 2011). It also sorts and stores location data (latitude, longitude) with reference to date and time. The number of studies using accelerometers to measure children's physical activity levels has been rapidly increasing (Cooper et al. 2005; Hume et al. 2005; Salmon et al. 2005; Treuth et al. 2005; Sallis et al. 2002; Cooper et al. 2003; Cradock et al. 2007; Hume et al. 2007; Baquet et al. 2007; Brockman et al. 2010; Craggs et al. 2011; Pabayo et al. 2011; Toftager et al. 2011; Van Sluijs et al. 2011). Yet, there are limited number of studies which used GPS and accelerometer simultaneously (Yin et al. 2013; Jerrett, et al. 2013; Dunton et al. 2013). In this study, accelerometers (Actigraph wGT3X-BT, ActiGraph LLC, Figure 1) were used to measure the intensity of the physical activity and GPS (BT-Q1000XT Travel Recorder XT, QStarz International Co., Ltd., Figure 2) were used to identify the location where each type of activity (sedentary, light, moderate and vigorous) took place.

Figure 2. GPS device: QStarz BT-Q1000XT Travel Recorder XT



3. A CASE STUDY TO MAP LOCATIONS OF PHYSICAL ACTIVITY INTENSITIES VIA COMBINED ACCELEROMETER AND GPS DATA

3.1 Equipment Acquisition

The cost of an accelerometer-GPS pair is about 400 $ and the cost of software to transfer accelerometer data to a personal computer is about 5000 $. Given that, objective measures of physical activity costs encourage researchers to apply for funding their research. Moreover such costs, determines limited sample sizes for such research. On the other hand, low costs of subjective measures (survey forms) make such measures more preferable for short term research. This study was funded by Dokuz Eylul University, Department of Scientific Research Projects. 40 accelerometer-GPS pairs and related software was obtained via this financial support.

3.2 Participants

This study was approved by Dokuz Eylul University Ethics Committee. All participants (child-parent pairs) signed an "Informed Consent Form". This form informed participants that; (1) the devices (accelerometers and GPS) have no effect on users' health, (2) they have no responsibility for the device damages or lost, and (3) they can withdraw anytime they want without any penalty. The participants were supposed to devote themselves to use the devices for a week (which may be uncomfortable for some) and our experience showed that people were reluctant to volunteer in such kind of long term studies in Turkey. 56 people were informed about the study with permissions from a private sports school administrators.4 people declined to participate and 52 child – parent pairs volunteered to participate in this study. All children were either attending to basketball classes or swimming classes.

Moreover, such kind of research inherits the risk of participants' failure to return the devices as is. One would expect higher probability for a device to be lost, when the research focus group is children. In this study the devices were distributed to 52 children, and one participant lost a pair of accelerometer – GPS.

The procedure followed in this study aims to diminish the methodological biases. First the researcher (first author of this study) provides information about the study to all child – parent pairs who accepted to participate. Then the devices were distributed and children were helped to adjust the elastic belt (which carries the devices) to their waist. Parents were warned to re-charge the GPS batteries via a USB cable every night when child sleeps. They were also warned not to turn off the GPS devices. The devices were collected after 7 days. Since there were only 40 accelerometer, the study was held with two groups in two weeks. 33 basketball class members worn the devices for one week and 19 swimming class members worn the devices the other week. The weather conditions in two weeks did not show substantial differences. However, it is necessary to note that the number of devices determines the sample size as the research could not be extended in time due to the seasonal variations.

3.3 Data Management

The accelerometer data was transferred to a personal computer via ActiLife software (Actigraph, LLC). Children's height, weight and age information (which was provided by the sports school teachers) was entered to the software. Each child's physical activity level per minute intervals was calculated via Freedson (2005) algorithm as below:

METs=2.757 + [0.0015 x counts/min] - [0.08957 x age (year)] - [0.000038 x counts/min x age (year)].

Then, for each minute each child’s physical activity levels were classified in three groups as: (1) sedentary (1 METs), (2) light activity (1 - 2.9 METs), (3) moderate to vigorous activity (more than 3 METs) based on METs (unit of metabolic equivalent). Moderate to vigorous activities are called MVPA.

GPS data was transferred to a personal computer via QStarz software. The GPS data contained date, time, latitude, longitude, altitude, and speed information for 1 minute epochs. Accelerometer data were aligned with the next closest GPS data via ActiLife's GPS Correlator. This matched data involves information about the intensity and location of physical activity for one minute intervals. The data was coded as "missing value" when activity counts were zero (the participant was not wearing the belt) or when the longitude-latitude information was missing. Missing values were eliminated from the analyses.

3.4 Mapping

The matched data was transferred to ArcGIS 10.0 by adding longitude-latitude information as XY data and converting the data to a shape file. For each one minute interval the intensity and the location of the physical activity was showed with a “point” on the map. "Data Management Tools" were used to define the coordinate system as Geographic Coordinate System WGS 184. The raster image derived from the “ArcGIS basemap library” was used as the base map. The activity points perfectly matched with this base map (Figure 3). Besides, for each child the location of their house, school, and sports school were represented as points on the maps. Figure 3 shows the activity map of one child. This is repeated for all participants. “Red” dots represents MVPA, “green” dots represents low physical activity, “yellow” dots represents sedentary behavior. Note, activity maps involve information about activities in mobilized vehicles as well as walking, running and other types of activities. To eliminate the mobilized data from the sample, the activities for which the speed is higher than 5 km per hour were eliminated. In general, activity speeds of 5 km per hour or above are assumed to be mobilized activities (Cetintahra & Hepguzel, 2014). Figure 4 represents a closer look to the child's activities and shows that majority of activities were achieved in the close vicinity of the child's home and school and on the route between home and school (Figure 4).

Figure 3. One child's physical activity location's map

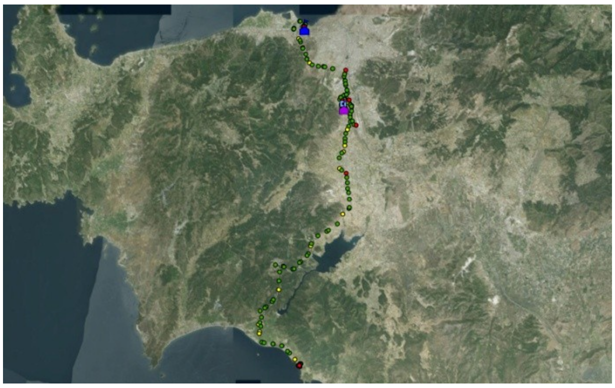
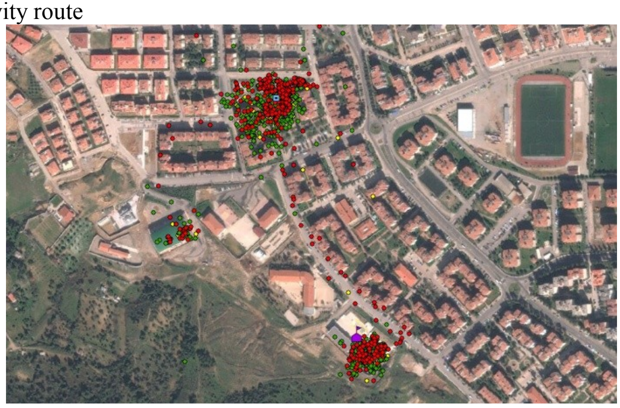


Figure 4. Activity route



Note, when the base map is converted from raster image to a vector map (showing street network and land use) more analyses are on call. However, production of a vector base map is time consuming and labor intensive. For the study area, vector data (information about street network and land use) have been produced by Izmir Metropolitan Municipality; however, it has been rarely shared. In order to use this data for academic research, funding is necessary. In brief research as such could be costly in developing countries even when the data is available.

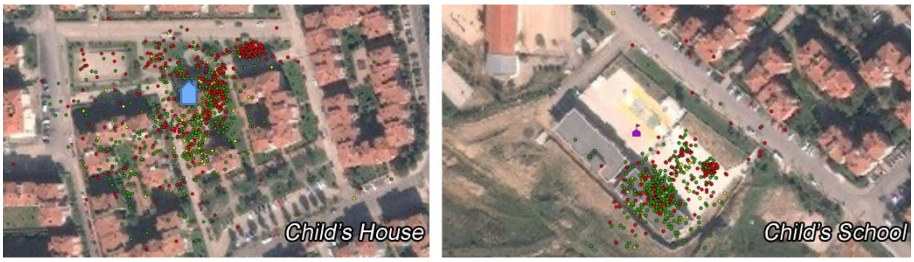
4. CONCLUSION

In order to collect data about physical activity intensity and location, two types of measures could be used: (1) subjective and (2) objective (Yin et al. 2013). Subjective measures may involve biased data but easy to apply to larger populations (Ward et al. 2005). However, data on exact location of physical activity could not be collected only via subjective measures (Dueker et al. 2013). Objective measures that depend on accelerometer and GPS devices may provide more accurate data about the physical activity and provides information about the exact location of physical activity with some deviation in distances. This deviation in distances could influence the results if sensitive analyses are aimed for outdoor environments. For example, data from objective measures may fail to differentiate indoor and outdoor activities (Figure 5).

Conducting a research using objective measures of physical activity could be troublesome in certain populations that are not used to these methods. First of all, our experience showed that a few people volunteered to use accelerometer and GPS devices for one week. More over people who volunteer fails to complete the full session. For example in this study among 52 volunteers, one child lost the device and 7 children use the devices less than two days. Although the devices were too compact (accelerometer is about 19 grams with a size of 4.6cm x 3.3cm x 1.5cm and GPS is about 64.7 grams with a size of 7.2cm x 4.7cm x 2cm) to carry on, three children failed to carry on the devices for a full day and two children reported that carrying such devices feels uncomfortable. However, to date the technological developments could not offer more ergonomic devices for children.

Given the advantages and disadvantages of objective and subjective measures, it is better to support objective data with subjective ones. GPS devices could have bad connection with satellite (and produce biased data) in closed spaces; in areas of high building density and height (Quigg et al. 2010; Kreen et al. 2011), and cloudy weather condition (Almanza et al. 2012). In such conditions, the data achieved from the device is unreliable. For instance in this study, according to parents survey, one child was usually active at home. However, when his / her accelerometer and GPS data were analyzed and the locations of activities were mapped, the child seems to spend time in a park which is in the close vicinity of his / her house (Figure 5). Given that, one may claim that this study fails to differentiate the reliable and unreliable data. This limitation could be eliminated if data from GPS and accelerometer could be checked (and proved for accuracy) with data from travel-diaries which focus travelling to a destination (Handy et al. 2002). A better extension of this study should use diaries as well as survey forms to improve the data quality.

Figure 5. Physical activity counts closer to child's house and school



In brief, it is important to understand the relation between the built environment and people's (as well as children) physical activity behavior. Thus it is necessary to uncover where children are active and inactive. The simultaneous use of accelerometers and GPS devices could provide such information with some expense (such as high cost of using these devices for a long time and biased location information due to deviations in distances). Yet, this study aims to introduce a new methodology to map children's activity. Future research which develops this methodology to improve data quality (decrease distance deviations and find a better way to differentiate indoor and outdoor activities) would be a better extension of this study.

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