

VYUŽITÍ GPS PŘÍSTROJŮ PRO MONITORING POHYBOVÉ AKTIVITY – POTENCIÁL A LIMITY

THE USE OF GPS DEVICES TO MONITOR PHYSICAL ACTIVITY - POTENTIAL AND LIMITS

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ABSTRACT

Physical activity (PA) is one of the factors that positively affect health. Recent studies confirm that the type of the built environment can influence the physical activity behaviour. This relationship can be examined by a variety of methods (questionnaires, pedometers and accelerometers). At present, use of geographic information systems (GIS) and satellite positioning systems such as the global positioning system (GPS) appears to be very appropriate. Using GPS devices can locate PA in space and time. This information can help us understand the issue of active lifestyle. The main objective of this study is to clarify the use of GPS technology for PA monitoring in the Czech Republic. PA monitoring using GPS devices was conducted in Olomouc in 2014. One-week measurement was performed by 160 students (63 boys) from three primary schools. PA intensity was monitored by ActiGraph GT3X and localized by GPS logger Holux RCV – 3000. The combination of data from the accelerometer and GPS logger allows us to predict more easily where and at what intensity level the participants were active. Data imported into GIS can be analyzed and compared with the type of environment. We can easily estimate the influence of environmental elements such as parks or bike paths to the structure of participants' PA. The use of GPS devices can very effectively contribute to the localization of PA and facilitate formulation of recommendations to promote PA in municipal practice. Such recommendations can be helpful in improving health of the population. However, usage of these devices in practice has many restrictions such as inaccuracy, battery capacity, slow first satellite connection and negative participants' attitude towards this type of research.

Keywords: environment; GIS; health; PALMS; PA localization

SOUHRN

Zdraví člověka ovlivňuje celá řada faktorů. Jedním z faktorů, který zdraví člověka ovlivňuje pozitivně je pohybová aktivita (PA). Současné studie potvrzují, že typ zastavěného prostředí může pohybové chování ovlivnit. Tento vztah je možné zkoumat pomocí mnoha různých metod. V minulosti byly využívány dotazníky, krokoměry a akcelerometry. V současnosti se ukazuje jako velmi vhodné využití geografických informačních systémů (GIS) a družicových polohových systémů jako je například globální poziční systém (GPS). Pomocí přístrojů GPS můžeme lokalizovat PA v prostoru a čase. Tyto informace mohou přispět k porozumění problematiky aktivního životního stylu. Hlavním cílem této studie je ověřit využití GPS technologie pro monitoring PA v českém prostředí. Monitoring PA s využitím GPS přístrojů proběhl v Olomouci v roce 2014. Měření se zúčastnilo 160 žáků (63 chlapců) ze třech základních škol. Sběr dat trval 7 dní. Intenzita PA byla monitorována přístrojem ActiGraph GT3X a lokalizována přístrojem GPS logger Holux RCV – 3000. Kombinace dat z akcelerometru a GPS loggeru nám umožňuje snáze odhadnout kde, a jak intenzivně se účastník pohyboval. Data importována do GIS je možno analyzovat a porovnávat například s typem zástavby nebo odhadnout vliv existence parků na strukturu PA obyvatel. Využití GPS přístrojů může velmi efektivně přispět k lokalizaci PA a napomoci tak k tvorbě doporučení do komunální praxe, která přispěje k podpoře PA a tím zlepšení zdraví populace. Využití těchto přístrojů má však v praxi řadu omezení jako jsou na-

příklad přesnost zařízení, kapacita baterie, pomalé připojení a negativní přístup participantů a jejich rodičů k tomuto typu výzkumu.

Klíčová slova: prostředí; GIS; zdraví; PALMS; lokalizace PA

Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985). Moderate PA, such as walking or riding a bike, positively affects human health (WHO, 2015). Previous studies showed that built environment may have impact on physical activity behaviour (Frank, Schmid, Sallis, Chapman & Saelens, 2005; Humpel, Owen & Leslie, 2002; McCormack, Giles-Corti & Bulsara, 2008), in particular on active transport (Van Dyck, Deforche, Cardon & De Bourdeaudhuij, 2009). The association between built environment and PA has been assessed by numerous interdisciplinary studies (Frank, Schmid, Sallis, Chapman & Saelens, 2005; Humpel, Owen & Leslie, 2002; McCormack, Giles-Corti & Bulsara, 2008; Saelens, Sallis, Black & Chen, 2003; Sallis, Bauman & Pratt, 1998; Van Dyck, Deforche, Cardon & De Bourdeaudhuij, 2009; Bauman et al, 2009; Mitáš, Dygrýn & Frömel, 2008). The influence of built environment on human PA might be assessed using questionnaires, pedometers, accelerometers and geographic information systems (GIS) (Oliver, Badland, Mavoa & Duncan, 2010). Usage of satellite positioning systems is considered as a fairly new method to assess the associations between built environment and PA both in the Czech and foreign literature.

Global positioning system (GPS) is the most widespread positioning system currently. The GPS is a navigation system used to determine position, velocity and time. This technology has been initially developed for the purposes of the U.S. Army. Nowadays, it is used often for civil navigation and research activities. The GPS devices allow us to localize place and duration of physical activities. This provides us with new information that can contribute to deeper understanding of the active lifestyle issues. In the past years, the GPS data has been collected across all population groups (Krenn et al., 2011). The studies have often combined the GPS-derived data with objective PA monitoring using accelerometers (Jones, Coombes, Griffin & van Sluijs, 2009; Quigg, Gray, Reeder, Holt & Waters, 2010; Troped, Wilson, Matthews, Cromley & Melly, 2010). Using the records from the GPS devices, it is also possible to specify individual physical activity behaviour, such as walking, running, riding a bike or using other mode of transport, more accurately. The studies might help investigate where respondents have the highest energy expenditure during physical activities (Kerr et al., 2011). Moreover, the GPS data provide information on time spent in buildings and free spaces (Cooper, Page, Wheeler, Hillsdon, Griew & Jago, 2010). The GPS technologies have become used also for identification of spaces with increased occurrence of risk behaviours including smoking, alcohol drinking and drug use. If urbanists or designers decide to avoid these or other social pathological phenomena related to environment in new built-up areas, they may find information of this nature essential (Kerr et al., 2011). Concerning the deteriorating health of population, the combination of GPS and PA monitoring appears as a potentially promising way of research in kinanthropology. The present study therefore aimed to analyse options of GPS technology use in the field of physical activity monitoring.

Methods

Participants

The PA monitoring using the GPS devices and accelerometers was conducted in Spring and Autumn 2014. In total, 160 pupils from three primary schools in Olomouc took part in the monitoring. The GPS record was obtained from 129 pupils, with 63 of them being boys ($13,7 \pm 0,9$ years; $167,4 \pm 10,8$ cm; $58,4 \pm 12,5$ kg; BMI $20,6 \pm 3,2$ kg · m⁻²) and 66 girls ($13,5 \pm 0,8$ years; $161,9 \pm 7,2$ cm; $51,0 \pm 9,7$ kg; BMI $19,4 \pm 3,1$ kg · m⁻²). The pupils were informed about the purpose of the study and functions and principles of the devices during a single school lesson. Then, they were shown demonstratively how to complete the accelerometer recording sheet. In the course of a week-long monitoring the participants had to charge the GPS logger several times. It was also emphasized to the participants that unless they provide the records on sufficient number of days (at least 4) and hours per day (at least 8), the data is useless for the research purposes. The study design was approved by the Ethics Committee of the Faculty of Physical Culture, Palacký University Olomouc.

Research techniques

Research material was distributed in plastic envelopes (A4 size). The content of the envelope included the GPS device, accelerometer, elastic band with two pockets intended for attachment of the devices, GPS device charger, research instructions, recording sheet for the ActiGraph accelerometer, information leaflet on the IPEN Adolescent project and questionnaire investigating environment and PA, which was to be filled in by participants' parents. The ActiGraph GT3X accelerometer was used to assess PA intensity. Concurrently with the accelerometer wearing, the participants were instructed to record the data into the recording sheet. They wrote down the time of start of wearing the accelerometer and the time they removed it. Moreover, the participants recorded the start and end of school, organized and unorganized PA. The wireless GPS logger Holux RCV – 3000 was used for PA localization. This device comprises the MT3329 chipset working at the frequency of 1 575 MHz. The logger sizes are $62 \times 41 \times 17$ millimetres and it weighs 53 grams. The device has 4 MB integrated memory and frequency of logging, i.e. recording of position was set to 5 seconds. The participants were shown and recommended to put devices on the belt on their right hip. They were also given a CZ charger and told to charge the logger each night.

Data cleaning and processing

The GPS data consists of immense number of points, with its record being disturbed by a number of external factors. Currently, there is not a unified methodology for cleaning and processing of the GPS data in the PA monitoring. In the present study, we used the Personal Activity and Location Measurement System (PALMS) software developed in the Center for Wireless and Population Health Systems, University of California, San Diego. The PALMS is a web application created to localize PA of individuals. Within the software, the GPS data processing consists of several stages:

- 1) Filtering out invalid points
- 2) Determining the points inside and outside buildings
- 3) Estimating the mode of transport
- 4) Investigation of locations where PA takes place

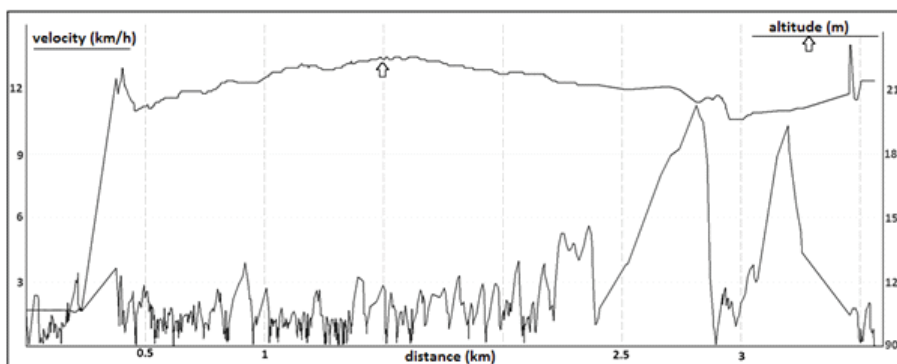
After the GPS data cleaning, the information on location is merged with accelerometer-derived data. The dataset can be then exported to geographic information systems (GIS) for data analyses. There is also an option to export the files in the KML format, which is suitable for data visualisation in the Google Earth interface.

Results

Due to communication with satellites orbiting the Earth, the GPS device is able to localize its position pretty accurately on the Earth surface. Based on the changes of the location and time records, it is possible to calculate the distance travelled and speed of movement. The GPS data also contain the information on altitude (Figure 1).

Obrázek 1./ Figure 1.

Příklad záznamu trasy v Olomouci./ The example of track record in Olomouc.

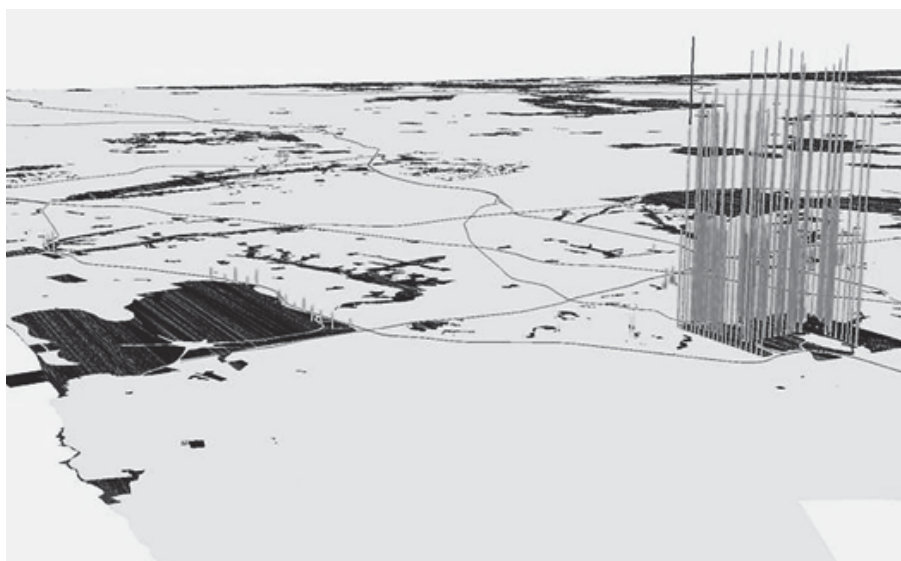


Poznámka./ Note. (velocity – rychlost, altitude – nadmořská výška, distance – vzdálenost).

In combination with the accelerometer-derived data, which provides information on PA intensity, it is possible to localize PA. Data derived from these two devices facilitate the estimation of where and at what intensity level a participant was physically active. The data imported to GIS might be analysed and compared, for instance, with type of built-up area. Another option of the GIS analysis is a visualization of PA intensity in the selected locations. Comparison of PA intensity in selected city parks enables to estimate for example, influence of park setting on the PA structure of inhabitants in its vicinity (Figure 2).

Obrázek 2./ Figure 2.

Intenzita pohybové aktivity ve vybraných městských parcích (upraveno dle PALMS, 2014)./ Physical activity intensity in the selected city parks (modified in line with PALMS, 2014).



If we were able to measure influence of specific elements of built environment on PA or active transport, it would promote development of recommendations for PA promotion in specific communities. The aim of these practical recommendations is to develop active lifestyle of population and, in turn, to enhance their health.

Discussion

The accuracy of portable GPS loggers

To include the GPS devices to scientific research, it is important to focus on accuracy of the data acquired. First, the devices were tested in a static position, i.e. the device does not change its location. In this case, the deviation of 1,5 – 10 m was observed for devices of specific types (Townshend, Worringham & Stewart, 2008). A more notable measurement error (40 – 50 m) was found in the environment where the signal between satellites and the device might be shaded (Duncan, Oliver & MacRae, 2011). In the built environment, such shading might be caused by so-called city canyons – high-rise buildings at both sides of a street. Another study (Rodriguez, Brown & Troped, 2005) shown the measurement deviation to be $0,90 \pm 0,74$ m in case that the GPS signal was not shaded.

Slow connection

During the initial start-up of the device or its recurrent attempts to re-establish communication with satellites, the process of track recording is often lagged. Such lagging is known as so-called cold start. The problem might occur when a person moves in a speed exceeding 50 km/h (Kerr et al., 2011). The device tries to adjust the position repeatedly, which hinders the establishment of stable connection with satellites. If a person enters a building with restricted connection at such a moment it might appear that the person did not move at all or data is shown as missing.

Physical obstacles

Communication with satellites might be interrupted by high-rise buildings, trees, tunnels or bridges. The older GPS devices lose signal under these conditions. The more recent models of the GPS devices are able to maintain connection even in the interiors of buildings. It mostly depends on construction materials and design of a building.

Environment

The GPS data might contain the record which is very unlikely (Figure 3). These deviations can be caused by actual location of a satellite at the orbit. The higher the satellite is above horizon, the better the signal is and the more accurate data is provided. The atmospheric conditions can affect the signal transfer as well (Jun, Guensler & Ogle, 2007).

Process complications

Adolescents' and their parents' attitude towards research is a very important and hardly influenceable variable. If the attitude of parents and adolescents is positive, the probability that data will be of high quality is pretty large. Using the examples (Figures 3 and 4) of two outputs we illustrate the variation in quality of data collected by the same devices, in the same school class, after the identical initial instructions by research team. As is apparent in Figure 3, the device was located almost exclusively at one place. The "beams" (lines running away from this point) are caused by the movement of satellites or incorrect transfer of GPS signal. Although it is theoretically possible that the participant was at a single place for the whole week, such data is useless for research and the record is classified as irrelevant. We therefore try to prepare the top-quality information materials for parents and personally persuade the participants about the importance of their attitude towards monitoring.

Obrázek 3./ Figure 3.

Příklad nekvalitního GPS záznamu trasy v Olomouci./ Example of a low-quality GPS data record in Olomouc.



Obrázek 4./ Figure 4.

Příklad kvalitního GPS záznamu trasy v Olomouci./ Example of a high-quality GPS data record in Olomouc.



It is also important to provide the participants and their parents with adequate feedback. If the feedback is comprehensible and professionally prepared, the chance to conduct similar research at the same school rises. The studies investigating PA by pedometer or accelerometer do not usually encounter issues with compliance with requested device wearing time. However, it is problematic when the GPS device is a part of research. Based on our experience, the adolescent participants have a feeling of being tracked. Thus, it is essential to emphasise the information that the GPS logger only records the data on location and it is impossible to track it in real time.

The combination of two devices might be a complication during research. The participants must wear two devices attached to a belt and, as result, receive a lot of information to comply with during a week-long monitoring. It is, however, desirable trend of modernisation and the combination of these two devices' functions into a single one – for instance sport trackers. The capacity of the GPS battery might be a limitation for studies conducted over several days. To avoid loss of data because the device turned off during day, it is recommended to remind the participants to charging them by text messages. Furthermore, it is reasonable to advise them to charge the device at such a place so that they will notice it on the next day (e.g. next to their cell phone or bed).

Information technologies and software could be considered as another limitation. Prior to monitoring, the devices were charged and tested. Despite, 20 % of the GPS loggers contained no data after the research. We cooperated with 160 students and because of limitations due to information technologies we were able to retrieve 129 records on routes in the required gpx format.

Conclusions

Thanks to the combination of the GPS devices recording location on the Earth surface and accelerometers monitoring PA volume and intensity we are able to localize the activity. If we know where and under what conditions the PA takes place, we will be able to develop suitable recommendations for communities, which will facilitate PA promotion. PA localization using the GPS devices is,

however, limited by several factors including accuracy of the device, battery capacity, slow connection, influence of high-rise objects and hesitant attitude of participants and their parents toward this type of research.¹

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¹This paper was supported by the research grant of Czech Science Foundation (No. 14-26896S) "Multifactorial research on built environment, active lifestyle and physical fitness in Czech adolescents" and Palacký University, Internal university grant (IGA_FTK_2015_003) "New technologies and approaches to physical activity monitoring: Utilization in kinanthropology research".

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