AXMS: OPTIMAL TOOL FOR INTRAMURAL EXERCISE MONITORING

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ABSTRACT

School requires an affordable and sustainable monitoring system to deliver cost-effective physical activity program. Experiments showed that pedometer-based system is effective but not sustainable due to the intensive labor for data collection and device maintenance. In this article, we first urge the importance of intramural exercise program and then analyze the requirement to measure it. A system based on radio frequency identification technology is invented based on the analysis and realistic considerations. Experience in operating it showed that data collecting work and system maintenance burden can be saved. We conclude that even the low cost pedometers cannot be a feasible solution within decade due to the need of data collecting work. An alternative is to promote intramural exercise which can be automatically measured.

Keywords: Radio frequency identification, Physical activity measurement, School-based physical activity promotion, Pedometer.

1. INTRODUCTION

Regular, brisk exercise reduces the risk of coronary heart disease, diabetes, hypertension, and bowel cancer (United States Department of Health, 1996). One engages in regular exercise of a period of thirty to sixty minutes a day, five days a week, can reduce risks in getting cancer, type 2 diabetes, heart disease, and osteoporosis and can prevent mental problems such as anxiety and depression (Strong et al., 2005). Unfortunately, many young people do not engage in recommended level of physical activity. In addition, physical activity declines precipitously with age among adolescents (Adams, Schoenborn, Moss, Warren, & Kann, 1995; Kann et al., 1996). Since most of them are attending schools, schools have the potential and responsibility to slow this age-related decline in physical activity and to help students in establishing lifelong physical activity habit.

School, however, is a sedentary setting away from home. Students may spend 8-9 hours long sitting in classrooms. In urbanized area, campus is one of the few places that students and nearby community inhabitants may engage in regular exercise. Intramural exercise program is a proper way to alleviate the sedentary nature of school and contribute to students' PA level. Supervised program such as physical education course has need urged to increase PA hours among youths. It, however, can result in curriculum competition and the budget of supervising labor. An unsupervised program such as that in extracurricular setting has the problem of low attendance rate (Lubans et al., 2014). To maintain participants' adherence and increase their incentive, the program may objectively measures each participant's physical activity so that important constructs of social cognitive theory, such as self-monitoring and tailored feedback, can be provided.

The measurement can be carried out the by relatively low-cost pedometer, waist-mounted accelerometers, or position sensors (e.g. GPS), etc. Studies of pedometer-based PA program in school setting have shown following advantages: 1) pedometer can facilitate increased PA among youths; 2) pedometer provided an incentive to engage with other activities but the sustainability of...
2. THE MEASUREMENT OF PA AND INTRAMURAL EXERCISES

Define a PA session as the period an individual has engaged a certain type of PA, e.g. walking, sleeping, and studying, on a certain place. The PA session can be described by the PA type, the space in which the PA is engaged, the duration of the session, and the energy expended for the session. The energy expended is often quantized by number of METs (metabolic equivalents). One MET, which is equal to 3.5ml/kg per minute, is the resting oxygen consumption of a resting human being after dividing his body weight (American College of Sports Medicine, 2005). An instrument in the lab may directly measure oxygen consumption of a PA session in a defined space of specific PA type for a defined period to obtain accurate energy expenditure (EE). On the other hand, a pedometer or an accelerometer can respectively measure a person's step count or acceleration without knowing the space, duration, and PA type of the person's PA session. They give the convenience in measuring a person's daily activity but also introduce uncertainty in the measurement result. The accuracy of the measurement result is thus limited.

Wearable devices are normally operated by power of a battery and measure a person's activity autonomously. A population-level PA program thus needs to collect data from them periodically to realize the activity level of program participants. This is an annoying task for PA program which uses pedometers. Either one or many program staffs need to read and record the activity data on the devices or need to remind participants to report or upload their activity data. Self-reporting, however, is likely to have data validity problem. Devices that can automatically report data has been proposed but are unaffordable to schools. Collecting data from wearable devices distributed to students is infeasible.

The only way to eliminate data collecting works is to automate the measurement. This can only be achieved through defining time, space, or PA type. The exercises prescribed by school-based PA program must cover most students and fit the system's capability to leverage the objective measurement. The most common exercise types on campus are walk, jog, swim, or ball games. Measuring students' PA intensity during a ball game is still a challenge. The intersection of the program and the population-level measurement is
thus the intramural walk and swimming program. Since the space and PA type are well defined, the measurement system can be simplified. Measuring a person’s walking activity can be further transformed into the identifying the person on the path. If check points that can identify a person are setup properly, the walking intensity can be. In this way, the measurement and recording of individuals' exercise can be automated elegantly. This eliminates the data collecting and recording works. A sustainable measurement system can thus be realized.

3. THE ARCHITECTURE OF AXMS

To realize the idea, an automatic exercise measurement system that based on the radio frequency identification (RFID) technology is implemented. An RFID system consists of a reader, an antenna, and a tag, as depicted in Figure 1. A tag is distributed to a program participant. Each check point is implemented by one or more sets of reader and antenna. A tag in the interrogation zone can harvest energy from the electromagnetic waves and send back its identity to the reader by way of the antenna.

RFID system can be active or passive based on type of the tags used. In our implementation the passive system is used due to the considerations of cost and ease of maintenance. A passive tag (Figure 2) contains only a coil and a chip that stores and sends back the tag's identity but not a battery. The tag can thus be sealed by plastic to make it waterproof and robust. Because of its tiny size and light weight, it causes least obtrusiveness when comparing to other wearable devices. Because of its simplicity and relief from battery, a passive tag is permanently operable and free of repairing and battery handling.

In our implementation of AXMS, four RFID systems were installed on running track of a university. Antennas are installed under the vertex points of two outermost running tracks as depicted in Figure 3. When an individual wearing a tag is running on the tracks, the tag's identification can be read by the RFID systems. A beep sound is then issued to notify the runner. During the walking or running session, the software of AXMS keeps calculating speed and accumulating the distance, the time period, and the EE according to ACSM's exercise guideline (ACSM, 2005). At the end of the session, the result is stored into database and sent to the runner and his relatives by email, i.e. the measurement and data collection are carried out automatically.

Swimming session is measured similarly. On each of the two opposite walls of a swimming channel, one antenna is mounted. One must wear his tag on wrist or ankle so that it can be read when he touches the wall to make a turn. Water-proof light in the water is used to indicate the successful reading.

A publically accessible web server is required if a program requests its participants to report PA data. AXMS saves the server through its automatic measurement and recording functions. A low cost embedded system is adequate to carry out the measurement and the administrating functions from health educators.

Figure 1: Components of an RFID reading unit.

Figure 2: An RFID tag laced on a running shore.

Figure 3: Architecture of AXMS.
4. A COMPARISON BETWEEN Pedometer-based system AND THE AXMS

One should consider hardware and software cost, availability of technical support, repairing cost, and burdens of data collection and device handling when selecting a PA monitoring system. A comparison of features among measurement systems using autonomous device and our AXMS is given in Table 1.

Due to the availability of free storage and some web service in the Internet, the setup cost of systems using pedometers or accelerometers is assumed to be zero. The setup cost of AXMS, however, consists of the cost of RFID readers, the antennas, construction work, wiring works, and the embedded system. The cost is about 10,000 dollars in our implementation excluding the software cost. The software is implemented by graduate students in six months. Because most of the software components such as operating system, database, and web server are based on open source, one can expect that software cost occupies only a small portion of system cost in the near future. Again, setting up the system and maintaining the system need technical personnel. In our implementation, two trained graduate students are adequate to handle the tasks. However, as the population size grows, the cost is lower than that of data collection and device maintenance.

From user's view point, a passive tag is less obtrusive so that users can thus engage in brisk walk, run, and swim as they used to do. However, students who dislike walking, running, and swimming are unlikely to participant the exercise program.

Since that routine path may be thought bored by students, it is suggested AXMS is installed on running path of distinct scenes. From the view point of health educators, AXMS may have following advantages: 1) Capacity: The number of persons whose PA can be measured depends on the capacity of the exercising path, not the system itself. 2) Scalability: Only new tags have to be purchased when population size grows. Only tasks of distributing tags and initiating personal data are required. 3) Multipurpose: It can be used to train athletes or sports team. Prescribing walking or running speed and distance in a PA session is possible.

5. CONCLUSIONS

Many PA programs have confirmed that objective measurement can effectively increase participants' PA level. Yet, none of sustainable program based on the wearable devices is reported. Since activity monitors has shifted their role from a measurement tool to an intervention tool, School intends to leverage objective measurement to promote all students' PA has to consider both affordability and sustainability of a measurement system. We have shown that only when constraints are put on the PA sessions, can a simpler measurement system can be innovated. Next we propose an RFID-based measurement system to achieve affordability and sustainability. As we know, AXMS is the first system installed on campus for school-based PA promotion program.

AXMS, however, is merely a tool. Theory-based PA program based on it is required to motivate students to engage in exercises. With the system, schools may have chance to deliver a long term PA program.

The limitation of space can be alleviated if many AXMSs are installed and connected. When a participant engages in the exercise on sites where an AXMS is installed, his record can then be sent back to his home AXMS. The limitation of exercise types can also be alleviated if other RFID-based applications are developed, for example, AXMS at the destination of a hiking route.

Given the importance of cost-effectiveness in any health-related program, specific program needs a specific tool to enhance its effectiveness. A population-level PA program, e.g. school-based program, needs population-level measurement system. The AXMS presented in this article fits the need most.

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REFERENCES

statistics. Series 10, Data from the National Health Survey, (192), 1-51.


<table>
<thead>
<tr>
<th>Technology</th>
<th>Dumb pedometer</th>
<th>Omron HJ-323U</th>
<th>Nike+ FuelBand</th>
<th>AXMS</th>
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