Policy Forum

Measurement and Assessment of Physical Activity by Information and Communication Technology

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Abstract: This study provides explorative insights into the information and communication technology (ICT) for promoting the physical activity level. ICT has provided innovative ideas and perspectives for PA measurement, assessment, evaluation and health intervention. ICT that aims to increase exercise for the entire population should be of a well-oriented and easy-to-use design with the options of tailored and personalized feedback, coaching, and ranking and supporting; it should be capable of setting goals and working with a schedule and be accompanied by a website to provide overviews of the users' exercise results and progress.

Key words: Physical activity; Measurement; Assessment; Information and communication technology

INTRODUCTION

Sedentary behavior and physical activity (PA) are important issues of public health. It is well known that PA reduces the risk for cardiovascular diseases and diabetes and has substantial benefits for several conditions, including those that are associated with obesity, and that a passive lifestyle subsequently decreases the quality of life by increasing hypertension, obesity, and type 2 diabetes mellitus[1-2].

An overall evaluation of the evidence suggests that important health benefits accrue in most children and youths who daily accumulate 60 or more minutes of moderate to vigorous PA (MVPA). For adults and elderly individuals, risk reduction routinely occurs at levels of 150 min of at least moderate to intensity PA per week[3-4]. There is strong scientific evidence that regular PA extensively benefits the health in adults aged 18-64 years and in older adults aged ≥ 65 years. In some cases, the evidence of health benefits is the strongest in older adults because the outcomes related to inactivity are more common in them.

Globally, in 2010, approximately 23% of the adults aged > 18 years and more than 80% of the school-going adolescents aged 11-17 years had insufficient PA[5]. Therefore, it is important to increase the engagement in PA with the most effective methods to achieve this goal. The objective measurement and evaluation of the daily PA level is of great significance for the development of health interventions.

With rapid growth in Internet accessibility and improvements in technology, a growing population of research has employed information and communication technology (ICT), such as mobile health and wearable devices, to promote PA for addressing the increasing rates of obesity and chronic diseases. ICT has no universal definition, and it is related to technologies facilitating the transfer of information and various types of electronically-mediated communications. At the end of 2016, seven billion people (95% of the global population) were living in an area that had mobile-cellular network coverage, and it was estimated that globally there were approximately 3.6 billion mobile-broadband subscriptions[6]. So it is not surprising that research on the use of ICT intervention has escalated in the past decade.

Effective measurement is the basis and key for conducting relevant research. Measurement and assessment have been transformed from traditional methods to ICT, and precision and accuracy have also improved in practice. This article attempts to analyze various current measurement instruments and PA intervention researches to explore efficient methods among them to accordingly make recommendations for different populations to promote their PA levels and to focus on promoting further research in the field of public health.

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MEASUREMENT METHODS OF PA

Measurement methods of PA can be divided into subjective and objective evaluation methods. Subjective methods include diaries, logs, and questionnaires; e.g., international physical activity questionnaires. Subjective measurement, as part of a self-report survey, is the most extensively used. The most common method for assessing the PA level is the questionnaire, but as a subjective measurement method, several kinds of bias often occur[7], such as the recall bias to quantify PA for children and elderly individuals. Therefore, objective methods, such as accelerometers, provide a considerably greater precision of measurement[8]. Thus, seeking efficient methods to quantify PA has become a necessity.

Objective methods include observations, doubly labeled water (DLW), motion sensors (e.g., pedometers and accelerometers), and heart rate (HR) monitors. DLW is the most effective and reliable method to measure the total energy expenditure of free-living conditions, which is the gold standard[9-10]. HR monitors are based on physiological sensors which is useful as a physiological variable because it linearly and proportionately increases with exercise intensity and subsequently with oxygen uptake[11]. Some studies have concluded that the energy expenditure can be predicted from HR after adjusting for age, sex, and body mass[12], because of the low correlation between energy expenditure and HR in light-intensity PA.

Movement sensors (e.g., pedometers and accelerometers) report their outcomes in activity counts per unit of time, which are the product of the frequency and intensity of movement. Therefore, movement sensors not only can provide temporal information regarding specific variables, such as the total amount, frequency, and duration of PA[13], but also monitor the accumulation of MVPA and/or sedentary behavior with the development of population-specific cut-off points for activity counts per minute. Early pedometers were mechanical with a 2D-vibration sensor; currently, 3D-electronic pedometers have replaced them and have become a popular way for people to keep track of their recommended 10,000 daily steps; these are worn around the waist or on the wrist and include Omron™, Walking FIT™[14]. Among them, wrist pedometers, such as the Basis B1 health watch and Fit Flex, are popular and have been used as devices for monitoring PA. They are effective in detecting the total movement over a given timeframe, but may be less effective in distinguishing the types of PA. In other words, they might be effective in detecting the duration of walking or sitting, but are unable to detect cycling or the difference between sitting and watching TV/working[15]. However, cycling, which is classified as a MVPA, is poorly measured by accelerometers[16].

The growing affordable, multi-sensor technologies, including the combination of physiological, contextual, and motion sensors, seem to have a great potential in recording PA, sleeping time, HR, and other daily activities. Recently, the use of smartphones with applications (apps) or a WeChat tool has also become popular. The users need not buy any pedometer device because a smartphone directly provides the pedometer function. A comparative study of accuracy between pedometers, wearable devices, and smartphone apps reported the relative differences in mean steps during 500- and 1,500-step trails ranging from -0.3% to 1.0%, -22.7% to 1.5%, and -6.7% to 6.2%. Compared with actual step counts, data from wearable devices differed more than from smartphone apps[17]. Moreover, an assessment using a questionnaire overestimated PA strata than that using an objective method, such as using a pedometer[18]. Gradually, the development of ICT has provided new measures for assessing PA. The researchers have begun to try ICT methods, which are gradually being used in epidemiologic research to validate traditional methods, such as questionnaires (Table 1).

PA INTERVENTIONS THROUGH ICT

To address the growing rates of chronic disease and to affect the global burden of non-communicable disease, most interventions targeting behavior change that aim to improve PA have been developed[19]. Traditionally, face-to-face interventions (i.e., a structured PA program and counseling) are considered to be the optimal means for changing health-related behavior in group-based conditions because of their effectiveness in promoting fitness and exercise duration[20]. However, time constraints, cost limitations, geographic restrictions, and competing demands make inter-personal contacts difficult, and hence, such interventions are not effective in a large population[21-22].

Mass media (i.e., TV, radio, and advertisements) has been considerably used to guide and assist behavioral changes because it has the potential to assess large number of individuals, while the generic content and feedback was characterized by a lack of personalization, which was mentioned as the reason why they were successful only in raising awareness but not in increasing the PA level[23]. Interventions through mass mailing[24] and print media[25] did not seem to have a significant impact on health behavior.

Nowadays, the rapid development of electronic technology is resulting in interactive and computerized health communications for promoting PA and improving health behavior. Numerous inspections have revealed that ICT intervention through a computer or an independent electronic device incorporating behavioral principles has contributed to large effect sizes on health behavior and a PA increase, while solely education intervention failed to produce the significant effects[26]. This paper fills a gap in the literature by empirically examining the impact of various types of ICT interventions among various PA promotions and their associated outcomes, including both behavioral process variables and health outcomes.

Mobile health (mHealth) or electronic health have become nearly ubiquitous, including the Internet, closed computer systems, mobile devices, and smartphone apps, which are referred to as the promising means of mobile computing and communication technologies that seek to either improve the understanding of health information or to use technology as a surrogate for health service delivery[27]. Utilizing mHealth leverage technology to improve the level of PA has been refined as an efficacious methodology[28].

Internet

The rapid growth in Internet coverage and improvements in technology has provided millions of people with the accessibility to vast amounts of health information. Internet and computer-based intervention have the potential benefits in improving the effectiveness of PA, the most important of which may be the cost savings associated with a lesser time consumption, and the computer is likely to increase the willingness to disclose sensitive information and to improve the consistency of exercise and acquisition of salient information. Nevertheless, machines lack flexibility and are unlikely to receive appropriate responses.

Meta-analysis of Internet-delivered interventions have supported the public health impact of producing small but significant increases in PA across a population that has the potential for obvious positive changes to reach large populations, especially to sedentary individuals[29]. The effectiveness of Internet-based PA promotion is associated with a more extensive use of planned behavior theory, an inclusion of more behavior change techniques, and an application of participant interaction methods[30]. Furthermore, enhancing website engagement was an important factor in relation to potential improvements,

Table 1. Common Types of Measuring Physical Activity

Common Types	2D Pedometers	3D Pedometers	Sport Band	Smartphone-pedometers	Apps	Watch-pedometers
Movement	Mechanical-pendulum sensor	3D-acceleration electronic sensor	Acceleration sensor + Physiological sensor + GPS	Acceleration sensor	Acceleration sensor + GPS	3D-acceleration electronic sensor + physiological sensor + GPS
Data storage	None	Yes	Yes	Yes	Yes	Yes
Calories, number of steps, distance	Yes	Yes	Yes	Yes	Yes	Yes
Speed	None	None	Yes	Yes	Yes	Yes
Wearable mode	Must be vertical with a belt clip	Free or use a band fixed on the wrist	Wrist	Free	-	Wrist
Brand	Manpo-meter from Japan	Walking FIT, Omron	Fitbit, Mi band	WeChat movement, QQ movement	Nike + running, Codoon, Langdong	Apple watch
Other functions	None	Timing	Heart rate, sleep time, cycling	-	Cycling, climbing (partial have)	Heart rate, sleep time

and a clear linear association was identified between the intensity of intervention and the healthy behavioral changes[31]. Intervention features, such as structured educational materials, tailored content, and interactive elements, were identified to enhance the effectiveness of intervention to produce a greater PA change, while email reminders and updated content tended to be not necessarily included in an attempt to optimize a behavior change[32].

Smartphone Apps

Rapid developments in mobile phones have encouraged the use of smartphone apps in health promotion. Approximately 31% of the smartphone users have used their phone to search for health information in 2012 compared with 17% in 2015, and 38% of health app users have downloaded an app for PA[33]. A smartphone not only combines the voice and text messaging functions but also provides powerful computing technology that can receive Internet access, wireless connectivity, sensing with other devices, and support of third-party applications, all which have opened up a new era for healthcare[34]. PA-related apps are available from major smartphone providers, such as iPhone, Android, and Nokia. Hundreds of exercise-focused apps have the potential to enhance the efforts to conveniently promote behavior change and provide real-time support at a low cost. The range of app interventions involving goal-setting, instruction, coaching, modeling, motivating, tailored feedback and social support towards exercise performance were identified as the most useful strategies to promote PA[35].

Several reviews on app interventions for promoting PA revealed that smartphone apps can be efficacious, although the magnitude of the intervention affect is limited. As for a different frequency, intensity, and duration of PA, apps that automatically track the taken steps and the progress to PA goals seemed to be preferred at various ages and genders, and they are user-friendly and sufficiently flexible for use[36]. A smartphone-based assessment of PA was revealed to have an average-to-excellent level of accuracy for various types of behavior[37].

College and university students preferred a PA app for detailed information on their progress that enable competition with friends by ranking or earning rewards in a private community, while they are not willing to share their regular PA accomplishments through social media[38]. PA app interventions commonly used as supplementary tools indicated a significant increase in the daily step activity[39], and they enhanced engagement and increased the levels of exercise in addition to website-delivered intervention[40]. Self-regulation features may be the most beneficial in a PA app for middle-aged women (mean age, 40.7 years; SD, 10.3 years) with opportunities to interact with others, and game-like activities seem to be attractive[41]. Features that target self-regulatory principles and integrate a music feature could successfully increase the overall MVPA in young and aging adults[42-43].

Wearable Technologies

The escalating field of healthcare information technology has developed a wide range of portable devices allowing comprehensive monitoring and regulation of individual movements. PA assessment method using an on-body sensing system, such as an external accelerometer, not only measures the steps taken and hours of sleep attained and keeps track of activity data but also detects temperature, HR, pressure, and strain. The latest wearable devices enable self-monitoring of daily or long-term goals and provide feedback on PA performance[44]. Physical sensors that measure and quantify electro-exercises have currently been of interest because of their unique characteristics, such as ultra-thinness, low modulus, light weight, high flexibility, and stretching ability[45]. They exploit the interfacing to the skin or to the organs and facilitate a low-cost wearable unobtrusive solution with electrical signals continuously generated by human activities, which provide a new opportunity for PA monitoring and promotion[46]. It has been estimated that by 2018, more than 13 million wearable devices will be integrated into wellness programs, and already employee wellness plans with the use of wearable devices are becoming increasingly popular to promote PA[47].

In fact, recent systematic reviews have demonstrated that the use of wearable activity monitoring devices, even the simplest one such as pedometers, is associated with significant increases in PA and reductions in the in-body mass index, blood pressure, disease burden, and healthcare costs[48-49]. Pedometers have been found to be the most sensitive to walking behavior, which is simple in output, literacy-friendly, and time-wise understandable to end-users[50]. Specifically, pedometers are both a reliable and a valid tool for encouraging the self-monitoring of PA and raising the PA level in risk groups[51], children, and adolescents[52]. Wearable cameras, consumer-grade accelerometers, and smart-watches are emerging as novel ways to impact an increasing PA[53]. Wearable cameras offer a perfect objective method available to capture and categorize the social and environmental context of activity behavior[54], while smart-watches have been investigated to provide immediate feedback, reminders, and alerts in supporting exercise[55].

Virtual and Augmented Reality

Virtual reality (VR) is the digital creation of a complete virtual environment, which enables the merging of virtual objects with real objects and lowers the barrier to entry for individuals engaging in virtual content. VR provides opportunities for repetitive, contextual practice and feedback consistent with the conditions for successful activity acquisition, so that the use of VR has increasingly attracted public interest for enhancing PA engagement. In contrast to VR, augmented reality (AR) inhibits the personal experience of reality through the superimposition of virtual elements on the current physical environment.

Existing evidence has supported the feasibility of a VR system promoting PA to address activity limitation, impairment, and weak participation in healthy individuals, elderly people and for rehabilitation in clinical populations[56]. Popular, commercially available gaming technologies have been commonly employed to encourage PA, which indicated a significant and positive effect on the PA of children[57]. The effectiveness of an AR feature was systematically reviewed in patients with diabetes to reveal that exercise involvement, insulin, blood glucose levels, and health quality were significantly improved[58].

EVALUATION AND FORECASTING

On account that physical inactivity imposes a heavy social and financial burden, it is essential to find innovative ways to promote PA at both individual and societal levels. Digitalization has given rise to the idea that PA could be promoted, among other means, through the use of technology. This has led to an increased interest in the potential of technological devices and applications as a component of PA interventions[59]. The technology that has been used in interventions to promote PA has included a broad range of software applications and services. Examples of such remote technologies are smartphones, computers, tablet computers, activity monitors, and pedometers.

Using ICT on PA intervention is an important method to improve human health, which has provided innovative ideas and perspectives for PA promotion. First of all, ICT, as the research of information acquisition, processing, and transmission, has a great influence on public health information accessibility, dissemination, and application. Secondly, ICT improve the techniques of personal information collection and analyses, and enhance the capacity and specificity of physician expertise, and then increase the quality of individual chronic disease risk assessment. Thirdly, ICT has a profound influence on the improvement of the health information literacy, which can formulate the comprehensive understanding and raise the self-management efficacy, and in the meantime reduce the burden of medical expenses. Furthermore, the innovative ICT can measure common health indicators and PA features objectively, identify human health subtle changes accurately, promote fitness and exercise involvement, and illustrate to produce healthy behavior autonomously.

Evidence on the effectiveness of using technology to promote PA is conflicting. Pedometers[60] and other Internet-based interventions have been found to be more promising than placebo or minimal treatments. Smartphone apps may be effective in increasing PA[61], although a systematic review with meta-analysis demonstrated the effect to be non-significant[62]. The present review demonstrates consistent evidence supporting the efficacy of improving psychosocial variables through ICT-based interventions (e.g., self-efficacy). For behavioral variables (the PA level), the evidence was less consistent. Unfortunately, there is insufficient information explaining the underlying mechanisms for change because several of the included studies have an incomplete theoretical foundation. There is insufficient information on the relative effectiveness of Internet *vs.* traditional interventions (e.g., a face-to-face method)[63]. Overall, it is important to obtain statistically relevant, up-to-date, and both scientifically and practically important information on the effect of ICT in promoting PA. Therefore, gaining information on the effect of technology in increasing PA requires sufficiently comparative studies.

Research using various PA devices, such as activity monitors or smartphone apps, has increased together with rapid advances in technology. Therefore, data need to be constantly updated to enable a comparison of the effectiveness of various features between the products. Future studies should compare the effectiveness of various technologies according to their features, such as interactivity. Another important factor to consider is the cost-effectiveness, which has not generally been investigated in the domain of technology and PA.

However, while valid information on the effect of technology requires studies with comparative frameworks, it is also important to examine whether a specific technology is more effective or acceptable in population and individual health intervention research. Valid measurement of PA is challenging. The present review could not confirm the effect of an ICT initiation strategy on intervention exposure and adherence rate because these data were not available in most of the included studies. Clearly, more studies are needed to investigate the impact of an ICT initiation strategy on an intervention exposure rate, adherence rate, and efficacy. Considering the rapid change and revolution in electronic devices and techniques, there is a huge concern that anything that is developed today may soon become obsolete and outdated. High quality and long-term research into ICT to support PA and health behavior should be emphasized and explored.

In conclusion, it is important for a healthy China infrastructure to develop theory-based, effective, and engaging, but a simple and well-ordered, ICT with a structured layout that is based on user preferences and opinions focusing on key features facilitating PA engagement, goal-setting, real-time feedback and motivation, expert consultation, and social networking. Health improvement based on ICT will promote social development and economic prosperity. The combination of ICT and PA research can effectively promote relevant national health policy-making and health information services. Future research should focus on behavior change to analyze the function, interface, and interaction of ICT to improve information technology for implementing PA intervention and for bringing to realization the healthy planning objectives in China.

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