DETERMINING A CONVENIENT MOBILE PEDOMETER APP AND ITS PERFORMANCE IN ASSESSING PHYSICAL ACTIVITY STATUS AMONG UNIVERSITY STUDENTS

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ABSTRACT

Introduction: Many young people nowadays have sedentary lifestyle which might contribute to obesity prevalence. With the technology advancement, pedometer mobile applications (apps) are now available to promote physical activity and track steps. Nevertheless, not many studies have systematically evaluated the convenience and reliability of these apps in objectively measuring physical activity. Thus, this study aimed to identify the most convenient pedometer app to be used in tracking the number of steps and validate it against a subjective assessment (self-reported) method using the International Physical Activity Questionnaire-Short Form (IPAQ-SF) in identifying physical activity status among university students. **Methods:** Undergraduate students at the International Islamic University Malaysia aged 18 to 27 years were recruited using convenient sampling. A preliminary study was conducted among 10 study participants to select between Accupedo® and Map My Walk® pedometer apps for tracking steps count. They were required to use both pedometer apps and rate their experience. Subsequently, the selected pedometer app (Accupedo® Pedometer) and the IPAQ were used to assess physical activity status of study participants (N=86) over three days (two weekdays and one weekend day). Data obtained by the pedometer app were categorized as low active, moderate active and active while IPAQ-SF data were categorized into low, moderate, and high status. The relative agreement between these data were analysed using Kappa statistics, cross-classification, and Pearson correlation. **Results:** It was found that 74% (based on IPAQ) and 91% (based on pedometer app) of the study participants were categorized as low active. The Kappa value was k=0.126 (p=0.016) indicating a slight but significant agreement between these two methods. Cross-classification demonstrated that 40% (n=34) of the study participants were correctly classified into the same tertiles whereas 16% (n=14) were grossly misclassified. In addition, the average steps count/day (by pedometer app) was significantly correlated (r=0.235, p=0.03) with total MET-minutes/week as recorded by the IPAQ-SF. **Conclusion:** The pedometer app was comparable to the IPAQ-SF in assessing physical activity status. This shows that a cost-free and convenient mobile app is applicable to be used for daily physical activity assessment among young people.

KEYWORDS: Pedometer app, IPAQ-SF, Physical activity, Mobile app

INTRODUCTION

The prevalence of overweight and obesity is rising around the world, and it has become a global issue. The modernisation of transportation is believed to reduce the physical activity level and lead to a sedentary lifestyle (Mohamad Nor et al., 2016). A study by Lee et al., (2014) found that daily physical activity and screen time were associated with measures of obesity during childhood. On the other hand, with the advancement in technology, people had the ability to monitor their own physical activity using a motion sensor device known as pedometer (Tudor-Locke et al., 2004). Pedometer is a self-reported method in measuring physical activity and at the same time as tools to motivate people to be active by monitoring the steps daily (Tudor-Locke, 2001). It is easy-to-use and offers cost-effective objective measure of physical activity (Strycker, Duncan, Chaumeton, Duncan, & Toobert, 2007). These devices are popular because they are simple, low cost, and able to catch up short durations of physical activity that commonly lacked in self-report measures. Pedometers provide cheap, objective, precise and reliable measurement of ambulatory activity by tracking number of steps taken per day. Other than pedometer, the use of accelerometer had been acknowledged in several research studies. Accelerometers are well-known devices considering the accuracy, ability to get a lot of data, and considerable ease of use especially in large studies (Westerterp, 2009). Nevertheless, they are costly and demand for technical expertise, individual programming, and particular hardware and software (Dishman, 1994). In addition, certain accelerometers are not able to distinguish walking intensity or body positions such as lying, sitting, and standing (Dollman et al., 2013).

Several studies have examined the relationship between pedometer use and body composition. One study found a positive association between pedometer-assessed ambulatory activity and body composition variables such as body mass index (BMI) and fat percentage (Tudor-Locke et al., 2001). In addition, correlation with biological predictors and outcome such as age and BMI can be made with pedometer data (Cleland, 2011). A study by Bassett et al., (1996) and Welk et al., (2000) had shown that pedometers give a precise and valid measure of walking activities in free-living circumstance. Furthermore, by using pedometers, it is associated with significant increase in physical activity and BMI values and blood pressure (Bravata et al., 2007). Somehow, pedometers can contribute to under- or over- calculating of steps. A pedometer which is less accurate would result in negative responses to the device, so it is not encouraged to be used (Melanson et al., 2004).

Previously, a pedometer is known as a device to count the steps. Nowadays, the increased number of pedometer applications (apps) and the rapid evolution of technology allow the smartphone to be used as steps counter (Presset et al., 2018). Additionally, the pedometer app can easily be downloaded from the online store. This allows the mobile phone to be used as a pedometer and measurement of physical activity to be done by a device already being used by many people (Akerberg, Lindén, & Folke, 2012). In Malaysia, the total number of smartphone users was estimated to reach 19.9 million (Statista, 2017).

There are several pedometer applications available in the Google Play Store (Google) and Apple App Store (Apple Inc). Despite this, not many have been systematically evaluated in terms of convenience and reliability as a tool that provides objective measurements of physical activity. Therefore, this study aimed to identify the most convenient pedometer application to be used in tracking the number of steps per day and validate it against the self-administered International Physical Activity Questionnaire-Short Form (IPAQ-SF). The research was conducted among university students as no similar study has been conducted among this population before. Furthermore, data on physical activity assessment using objective methods (such as pedometer and accelerometer) are still limited in Malaysia (Hazizi et al., 2012).

MATERIALS AND METHODS

Study Design and Population

A cross-sectional study was conducted among undergraduate students at International Islamic University Malaysia (IIUM) from December 2017 to February 2018. The sample size calculation was performed using the single proportion formula, considering a prevalence of 33.5% among inactive adults in Malaysia as reported in the National Health and Morbidity Survey (NHMS) 2015 study which yielded 86 respondents. Study participants were recruited using convenience sampling. The inclusion criteria included undergraduate students who were residing on the IIUM campus and available during the study period. On the other hand, students with physical disability or medical conditions that prevented them from engaging in physical activity were not eligible to participate in the study.

Phase I: Selection of the Most Convenient Pedometer Applications

An internet search for pedometer applications was conducted to select the apps to be used. Two apps (Map My Walk® and Accupedo® pedometers) were shortlisted since they fulfil these requirements: i) Compatibility in both Android® and Iphone® operating systems; ii) Free of charge; iii) Ability to reports number of steps, total distance, time, and calorie burnt.

Accupedo® is a precise pedometer app that monitors daily walking on the home screen of the phone (http://www.accupedo.com/). Intelligent 3D motion recognition algorithms are embedded to track only walking patterns. Non-walking activities will be filtered and ejected out. Accupedo® counts steps regardless of where the phone is located like pocket, waist belt, or bag. On the other hand, Map My Walk® functions by phone global positioning system (GPS) to track daily walking routines (http://www.wellocracy.com). The app tracks and displays distance, pace, speed, elevation, calories burned, and routes travelled on interactive map. These two apps were used in the preliminary study.

A preliminary study was conducted to determine the more convenient pedometer app between the two finalized apps. Ten participants who volunteered were included in the study. They were given an opportunity to install and use the pedometer applications (Map My Walk® and Accupedo®). To evaluate each of the apps, the study participants were instructed to answer a questionnaire that was adopted from the System Usability Scale (SUS) (https://www.usability.gov), a reliable tool originally created by John Brooke in 1986 for evaluating hardware, software, mobile devices, websites, and applications. The survey consisted of five statements with four different scales (1=Strongly disagree; 2=Disagree; 3= Agree; 4= Strongly agree) with a minimum score of five and a maximum of 20. The study participants were asked to rate their experience of using each of the pedometer apps.

Phase 2: Assessment of PA status using the selected pedometer app & IPAQ-SF

The participants (different than those in the preliminary study) were instructed to install the selected pedometer app in their mobile phone. They were requested to set and turn their pedometer app on for two weekdays and one weekend day. To ensure the accuracy in handling the pedometer app, the participants were given explanation on how to use it and then were asked to demonstrate their understanding. The phone was brought along with them from the time they started their activity in the morning until they retired for the day. Participants were asked to put aside their phones when bathing or swimming. The participants were reminded to do their physical activity as usual without any change. They were required to screenshot and sent the record of steps per day, distance, duration, and number of calories burnt from the pedometer app to the researcher each night before going to bed. In addition, the study participants were requested to complete online IPAQ-SF for each day by clicking a link sent via WhatsApp. It consists of four questions regarding time spent for vigorous activity, moderate activity, time spent for walking and time spent for sitting. The questionnaire was adapted from the original IPAQ-SF (7 days) that was obtained from the website (http://www.ipaq.ki.se). These procedures were done over the course of three days (two weekdays and one weekend day).

Data Analyses

The physical activity status using pedometer application was categorized according to Basset (2004) into sedentary, low active, somewhat active, and active categories. In this study, the level of physical activity was modified from four to three categories (low active; ≤7,499 steps/day, moderately active; 7,500-9999 steps/day and active; ≥10,000 steps/day) to suit the three physical activity levels according to the IPAQ-SF.

On the other hand, raw data from IPAQ-SF questionnaire were analysed based on "Guideline for Data Processing and Analysis and Recommendations for Data Cleaning and Processing" available in www.ipaq.ki.se. The IPAQ-SF uses the MET unit which stands for the metabolic equivalent of task. One MET is the amount of energy used while sitting quietly. Physical activities may be rated using METs to indicate their intensity. For example, reading may use about 1.3 METs while running may use 8-9 METs. Based on IPAQ Group (2002), the participants were categorized as having high physical activity if they accumulated at least one hour per day or more of moderate-intensity activity over and above the basal PA, or half an hour of vigorous-intensity activity over and above basal levels daily. Classification of moderate category is when the level of activity equivalent to "half an hour of at least moderate-intensity physical activity on most days". Low category was for those who do not meet the criteria for either in moderate or high category.

Statistical Analyses

The SPSS software, Version 21.0. was utilized to analyse the data. The alpha level is set at 0.05 and 95% of CI. Descriptive statistics were used to describe variables such as sex, gender, Kulliyyah, smartphone brand, physical activity status, as well as the preference of the participants between two shortlisted pedometer applications. It was presented and computed as mean ± SD. Histogram and Kolmogorov-Smirnov test were used to check for normality distribution. As the data for the number of steps from pedometer app and the total MET-minutes for three days were not normally distributed, the data were normalized by using log10. Relative agreement such as interrater reliability analysis using the Kappa statistics was utilized to determine the agreement between pedometer app and IPAQ-SF. Cross-classification was also done by classifying participants into tertiles (high, moderate, and low physical activity categories) based on the physical activity levels as assessed by pedometer app and IPAQ-SF. Lastly, Pearson's correlation was used to determine the potential association between the two variables, the average number of steps from pedometer app and total MET-minutes/week according to IPAQ-SF.

Ethical Approval & Participants' Consent

Ethical approval for this study was obtained from the IIUM Research Ethics Committee. Written informed consent was obtained from each study participant prior to data collection. All the data collected were strictly treated as confidential.

RESULTS AND DISCUSSIONS

Phase 1: Selection of Pedometer Application

In Phase 1 of the study, a total of 15 participants were initially recruited to evaluate their experience with the shortlisted pedometer applications. However, only 10 participants (three males and seven females) were able to complete the evaluation. Among the participants, eight used smartphones with the Android operating system, while two used smartphones with the iPhone® operating system.

Result shows that 90% (n=9) of the participants rated the Accupedo® pedometer as easier to use compared to only 40% (n=4) for the Map My Walk® pedometer. Regarding the cost criteria, all participants agreed that both pedometer applications were free of charge. Interestingly, 90% (n=9) of the participants preferred using the Accupedo® pedometer as it did not require the GPS, while only 30% enjoyed using the Map My Walk® pedometer that relied on GPS. This finding aligns with a study by Middelweerd et al. (2015), where GPS usage was associated with battery power depletion and participants often forgot to start the GPS tracking. However, 30% of the participants in our study still agreed that using GPS features was acceptable. Like the current study, some participants found GPS tracking to be more convenient due to real-time data display and automatic assessment of distance and speed. Overall, more than three-quarters (80%) of the participants preferred using the Accupedo® pedometer, considering it to be more convenient compared to the Map My Walk® pedometer application (40%).

Table 1 Comparison of scores between the Accupedo® and Map My Walk® pedometer applications (N=10)

	Score Comparison (Mean ± SD)	
Criteria	**Accupedo®**	**Map My Walk®**
Ease of use	3.6 ± 0.7	2.4 ± 0.8
Free of charge	3.6 ± 0.5	3.3 ± 0.5
GPS	3.4 ± 0.7	1.9 ± 1.1
Preference	3.3 ± 0.8	1.5 ± 0.7
Total score	**13.9 ± 2.0**	**9.1 ± 2.0**

Table 1 shows the comparison of total score rated by the participants for both pedometer apps. The Accupedo® pedometer consistently received higher scores across all criteria compared to Map My Walk® pedometer. This finding is consistent with a study conducted among 30 Dutch university students, where participants favoured an app design that was uncomplicated and well-organized (Middelweerd et al., 2015). The participants expressed a preference for a structured layout with only a few essential features that allowed for easy activity log and provided a clear overview of the results.

Similar results were reported by Rabin & Bock (2011) in their study involving fourteen adults aged 23-60 years who used three physical activity apps. These participants emphasized the importance of an app being user-friendly, applicable to various types of activities, capable of automatically tracking activity, and enabling goal setting.

In a different study conducted among 250 Chinese individuals with chronic disease, it was found that 47.2% of them reported difficulty in using physical activity apps as one main barrier in technology application. Moreover, the participants also expressed concerns about being charged extra fees for using the apps (Sun et al., 2017). Another study conducted in the Western country found that high data usage and hidden costs led to nearly half of the app users giving up on using them (Krebs & Duncan, 2015).

Therefore, based on the survey score, the Accupedo® was the most preferred pedometer app due to ease of use features, free of charge, not requiring GPS, and convenience. Thus, the Accupedo® pedometer app was then used in the next phase of this study.

Phase 2: Performance of the selected pedometer application

In Phase 2 of the study, a total of 86 students from various faculties participated, with the majority being female (85%). Analysis of the pedometer app readings revealed that most study participants (90.6%, n=78) were categorized as low active, as they achieved ≤7,499 steps per day (Table 2). Only 2.3% (n=2) of them were categorized as active, with step counts exceeding 10,000 per day. Additionally, based on the IPAQ-SF score, three-quarters of the study participants (74.4%, n=64) were classified as having low physical activity status, followed by moderate (18.6%, n=16) and high (9.3%, n=8) physical activity status.

Table 2 Physical activity status according to pedometer app (Accupedo®) and IPAQ-SF (N=86)

Physical Activity Status	Pedometer app (%)	IPAQ-SF (%)
Low Active /Low	90.6	74.4
Moderately Active/ Moderate	7.1	18.6
Active/ High	2.3	9.3

The IPAQ-SF was able to capture a higher percentage of active and moderately active study participants compared to the pedometer app. It could be explained that self-reported IPAQ-SF tended to overestimate physical activity level compared to the objective pedometer data. This finding was consistent with previous studies that have reported discrepancies between subjective and objective measures of physical activity (Ahmad et al., 2018; Sitthipornvorakul et al., 2014). Over-reporting in self-reported questionnaires like the IPAQ-SF is a recognized issue, and it may explain why some participants reported being active based on the IPAQ-SF but not the pedometer (Ahmad et al., 2018).

Next, the higher percentage of participants categorized as having low physical activity status according to the pedometer (91%) compared to the IPAQ-SF (74%) suggests that confounding factors, such as forgetting to wear the pedometer, battery depletion, or the pedometer being less sensitive to movements, may have contributed to under-counting (Ahmad et al., 2018). These findings are consistent with previous studies that have highlighted challenges related to pedometer usage, including wearing the pedometer, resetting it, and battery usage (Casey et al. 2014). Overall, self-reported measures such as the IPAQ-SF and objective data like pedometers can complement each other and provide a more comprehensive understanding of physical activity levels.

In the study, the relative agreement between objective data from pedometer applications and subjective data from the IPAQ was analysed using the Kappa statistics, cross-classification, and statistical correlation. The Kappa statistics was calculated to determine the consistency among the data collected from the pedometer application and IPAQ-SF, resulting in a Kappa value of k=0.126 (p=0.016), indicating a slight but significant agreement between the two methods. The cross-classification analysis was conducted to assess the ability of the IPAQ-SF and pedometer application to correctly classify individuals into high, moderate, and low physical activity categories. The results showed that approximately 40% (n=34) of the participants were correctly classified, while 16.3% (n=14) were grossly misclassified. Notably, there is a lack of previous comparison studies utilizing cross-classification between the IPAQ-SF and pedometer app. These findings suggest that although only a small number of study participants was relatively grossly misclassified, discrepancies between self-reported physical

activity levels and pedometer app readings did occur, potentially due to over-reporting in self-reported questionnaires like the IPAQ. Factors such as participants forgetting to set the pedometer app, battery depletion, or the app's sensitivity to movements may contribute to under-counting. A previous study by Casey et al (2014) reported challenges related to downloading and installing the app, carrying the phone, resetting the app in the mornings, and high battery usage. These findings highlight the importance of considering both subjective and objective measures of physical activity to obtain a comprehensive understanding of individuals' activity levels.

The correlation between the average number of steps and IPAQ-SF was shown in the form of a scatter plot (Figure 1). The average number of steps per day recorded by the pedometer application was found to be significantly correlated with the total MET-minutes/week according to the IPAQ (r=0.235, p=0.03). This correlation falls within the range reported in a systematic review study comparing direct versus self-report measures for assessing physical activity in adults, which ranged from -0.71 to 0.96 (Prince et al., 2008). Consistent with previous studies by Welk et al. (2000) and Bassett et al. (2004), significant and positive associations were found between questionnaire-based physical activity and step counts. In a similar study, it was shown that self-reported method can either overrate or underrate the measured parameter in comparison to objective method (Prince et al., 2008).

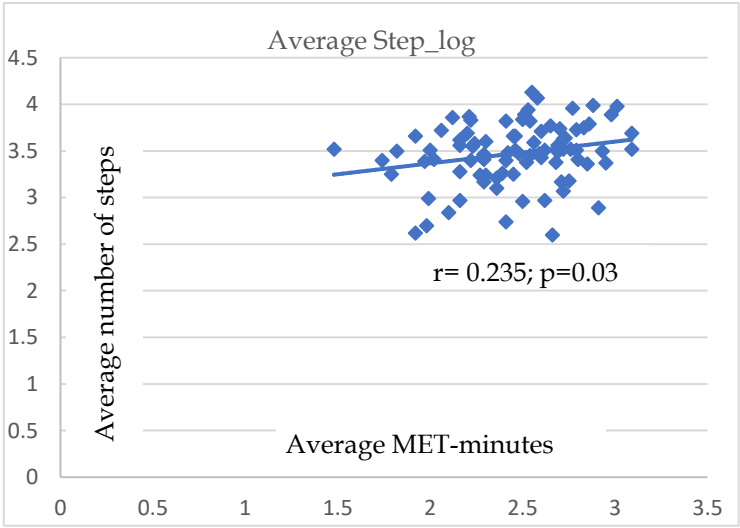

Figure 1 The average number of steps against average MET-minutes for 3 days (N=86)

To the best of our knowledge, this is the first assessment of physical activity status using a smartphone pedometer app and a comparison study between the pedometer app and IPAQ-SF specifically among university students in Malaysia. Moreover, the researchers made significant efforts to minimize errors by providing daily reminders to participants to turn on their pedometer app, submit screenshots of their data, and complete the IPAQ-SF questionnaire over the three-day study duration.

However, this study is not without its limitations. Some recruited participants did not complete the study procedures due to perceiving them as burdensome. Additionally, there were some others who were reluctant to participate due to the requirement of internet connection (mobile data) for testing the pedometer apps. A few potential participants were also unable to participate because the pedometer apps were not compatible with their mobile phone, insufficient mobile data, or storage capacity.

CONCLUSION

In conclusion, the findings of this study indicate that the Accupedo® pedometer app was the preferred choice among the participants in this study. Its ease of use, cost-effectiveness, and independence from GPS were key factors contributing to its preference. The chosen pedometer app demonstrated comparability to self-reported IPAQ-SF in determining physical activity status. While it is acknowledged that the step counts recorded by the pedometer app may be influenced by confounding factors, it remains a valuable tool for promoting daily physical activity. Further research is warranted to explore the long-term effectiveness and usability of pedometer apps in promoting sustained physical activity.

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REFERENCES

Ahmad, M. H., Salleh, R., Nor, N. S. M., Baharuddin, A., Hasani, W. S. R., Ali, O., & Aris, T. (2018). Comparison between self-reported physical activity (IPAQ-SF) and pedometer among overweight and obese women in the MyBFF@Home study. *BMC Women's Health, 18*(S1).

Akerberg, A., Lindén, M., & Folke, M. (2012). How Accurate are Pedometer Cell Phone Applications? A comparison between six applications, 5(0), 787–792.

Bassett, D. (2004). How many steps/day are enough? Preliminary pedometer indices for public health. Sports Medicine, 34(1), 1–8.

Bravata D. M., Smith-Splanger C., Sundaram V., Gienger A. L., Lin N., Lewis R., Stave C.D., Olkin I., Sirard J. R. (2007) Using Pedometers to Increase Physical Activity and Improve Health: A systematic review. JAMA 298 (19) : 2296-304.

Casey, M., Hayes, P. S., Glynn, F., Ólaighin, G., Heaney, D., & Murphy, A. W. (2014). Patients ' experiences of using a smartphone application to increase physical activity : the SMART MOVE qualitative study in primary care, (August), 500–508.

Cleland, V.J., Schmidt, M.D., Salmon, J., et al. (2011) Correlates of pedometer-measured and self-reported physical activity among young Australian adults. J Sci Med Sport. 14(6):496–503

Dishman RK. (1994) The measurement conundrum in exercise adherence research. Med Sci Sports Exerc. 26(11):1382–90.

Dollman J, Okely AD, Hardy L, Timperio A, Salmon J,Hills AP. A hitchhiker's guide to assessing young people's physical activity: deciding what method to use. J Sci Med Sport (2013) 12(5):518–25.

IPAQ Group. (2002). International Physical Activity Questionnaire IPAQ : Short Last 7 Days Self-Administered Format, (May 2001), 14.

Krebs, Paul & Duncan, D. (2015). Health App Use Among US Mobile Phone Owners: A National Survey. JMIR MHealth UHealth, 3(4).

Lee, S. T., Wong, J. E., Shanita, S. N., Ismail, M. N., & Poh, B. K. (2014). Daily physical activity and screen time, but not other sedentary activities, are associated with measures of obesity during childhood. International Journal of Environmental Research and Public Health, 12(1), 146-161.

Melanson, E. L., Knoll, J. R., Bell, M. L., Donahoo, W. T., Hill, J. O., Nysse, L. J., Levine, J. A. (2004). Commercially available pedometers: Considerations for accurate step counting. Preventive Medicine, 39(2), 361-368.

Middelweerd, A., Laan, D. M. Van Der, Stralen, M. M. Van, Mollee, J. S., Stuij, M., Velde, S. J., & Brug, J. (2015). What features do Dutch university students prefer in a smartphone application for promotion of physical activity? A qualitative approach, 111.

Mohamad Nor NS, Ambak R, Omar MA, Shahar S, Abdul Aziz NS, et al. (2016) Methodology of the My Body is Fit and Fabulous at Home (MyBFF@home): An Intervention Study to Combat Obesity Among Housewives in Malaysia. J Womens Health, Issues Care 5:6.

Presset, B., Laurenczy, B., Malatesta, D., & Barral, J. (2018). accuracy of a smartphone pedometer application according to different speeds and mobile phone locations in a laboratory context. Journal of Exercise Science & Fitness, 16(2), 43-48.

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Gorber, S. C., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review, 24.

Rabin, C & Bock, B. (2011). Desired Features of Smartphone applications promoting physical activity. Telemed J E Health, 10(801), 3.

Sitthipornvorakul, E., Janwantanakul, P., & Beek, A. J. v. d. (2014). Correlation between pedometer and the global physical activity questionnaire on physical activity measurement in office workers. BMC Research Notes, 7(1).

Strycker, L. A., Duncan, S. C., Chaumeton, N. R., Duncan, T. E., & Toobert, D. J. (2007). Reliability of pedometer data in samples of youth and older women, 8, 1–8.

Sun, L., Wang, Y., Greene, B., Xiao, Q., Jiao, C., Ji, M., & Wu, Y. (2017). Facilitators and barriers to using physical activity smartphone apps among Chinese patients with chronic diseases, (July 2015), 1–10.

Tudor-Locke, C., Ainsworth, B. E., Whitt, M. C., Thompson, R. W., Addy, C. L., & Jones, D. (2001). The relationship between pedometer-determined ambulatory activity and body composition variables. International Journal of Obesity, 25(11), 1571-1578.

Tudor-Locke, C., Ham, S. A., Macera, C. A., Ainsworth, B. E., Kirtland, K. A., Reis, J. P., & Kimsey, C. D. (2004). Descriptive Epidemiology of Pedometer- Determined Physical Activity. Medicine & Science in Sports & Exercise, 1567–1573.

Welk, G. J. (2002). Physical Activity Assessments for Health-Related Research. Human Kinetics.

Westerterp, K. R. (2009). Assessment of physical activity: a critical appraisal, 823828.