ORIGINAL ARTICLE

Mobile Application for Self-Assessment of Cardiorespiratory Fitness among Diabetic Patients

RAKHMAT ARI WIBOWO*, DENNY AGUSTININGSIH
Department of Physiology, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia
Correspondence to Rakhmat Ari Wibowo, Email: rakhmatari@mail.ugm.ac.id

ABSTRACT

Background: Exercise prescription is one of the essential cornerstones for managing type 2 diabetes mellitus. However, many type 2 diabetes mellitus patients have been reported as not engaging in proper exercise regimens due to the absence of assessment of their cardiorespiratory fitness level.
Aim: To test the accuracy of a mobile application in measuring heart rate and walking distance during a six-minute walk test among diabetic patients.
Methods: We performed a validation study of a mobile application in type 2 diabetes mellitus patients. Thirty-five participants performed a six-minute walk test using a mobile application. The distance estimated by the application was compared to the measured distance. In addition, the heart rate before the test and at the end of 6 minutes measured by the application was compared to the measured heart rate by pulse oximetry. The mobile application work with contact photoplethysmography in measuring heart rate and global positioning system in measuring walking distance.
Results: Walking distance and heart rate measurement using a mobile application correlated well with measured distance (r=0.898) and pulse oximetry, r=0.943 for heart rate before the test and r=0.953 for heart rate at the end of 6 minutes. The accuracy of the heart rate and walking distance measurements by application, reported in mean absolute error were 4.14±0.94bpm for heart rate measurement before the test, 4.46 ±0.93 for heart rate measurement at the end of 6 minutes, and 27.58 ±6.20 meter.
Conclusion: Our findings suggest that an Android-based smartphone application yields accurate heart rate and walking distance measurements during a six-minute walk test. Thus, a mobile application may be suitable for self-assessment of cardiorespiratory fitness among type 2 diabetes mellitus patients.
Keyword: Cardiorespiratory fitness; exercise; mobile application; six-minute walk test; type 2 diabetes mellitus

INTRODUCTION

A substantial body of evidence highlighted that regular exercise is one of the three cornerstones of type 2 diabetes care programs, together with tracking, pharmacotherapy and diet modification[1,2,3]. Moreover, a systematic review and meta-analysis suggested that proper supervised exercise resulted in enhanced glycemic control in patients with type 2 diabetes mellitus, independent of dietary intervention[4]. However, many patients with type 2 diabetes mellitus did not engage in the proper dose of exercise programs[5]. Also, current exercise referral scheme are not specific enough to allow a tailor-made exercise intervention for individual diabetes patient[6]. The lack of individually tailored exercise prescriptions could be due to the absence of regular assessment of cardiorespiratory fitness level.

The American Heart Association recommends regular assessment of cardiorespiratory fitness level as its importance in predicting mortality[7]. There are several methods of measuring cardiorespiratory fitness. The six-minute walk test (6MWT) is one of the simple methods for assessing cardiorespiratory fitness. The distance walked on a linear course at the end of 6 minutes could be used to assess the cardiorespiratory fitness level[8]. Despite its simplicity, 6MWT requires trained personnel and valuable personnel time. Also, several studies suggested that the addition of heart rate measurement could improve the accuracy of the 6MWT in predicting cardiorespiratory fitness[9]. However, the addition of heart rate measurement in a 6MWT requires more sophisticated equipment and more trained personnel than measuring the walking distance alone.

The smartphone technology advancements and the ubiquity of smartphones provide an opportunity to develop an application to help an individual in conducting a self-assessment of their cardiorespiratory fitness level. Global positioning system (GPS) tracking embedded in the smartphone allows measuring walking distance. Also, the camera and the flashlight in a smartphone could be leveraged to measure heart rate using contact photoplethysmography.

Recent study suggested that an IOS-based smartphone applicationcan accurately measure walking distance in a 6MWT[10]. Also, several mobile applications have been found to have good accuracy in measuring heart rate using contact photoplethysmography[11]. To the best of our knowledge, none of them has both functions together in one mobile application.
We have developed a mobile application (InaFit) which can both measure walking distance and measure heart rate. Therefore, this study aimed to evaluate the accuracy of the mobile application in measuring heart rate and walking distance during a 6MWT among patients with type 2 diabetes mellitus.

MATERIALS AND METHOD

InaFit application content: The InaFit is a mobile application on the Android Operating System. It consists of a real-time self-administration of the 6MWT with instructional text according to the American Thoracic

Society protocol (8). It records estimated distance traveled, travel duration, and heart rate. At the first start of the application, the user is asked to enter their birth of date, gender, height, and weight. Before each test, the application prompts the user to record their heart rate using photoplethysmography by placing their fingertips over the phone's primary camera. Then, the user can start the test by themselves. At the end of six minutes, the application instructs the user to stop walking and check their heart rate. Finally, all measurements and the interpretation of the results will be presented to the user and recorded in the database.

2.2. Technology. We tested the mobile application on four similar portable phones (Xiaomi Redmi Note 4).Each phone has 13 MP primary camera with CMOS sensor, 1.12µm pixel size, f/2.0 aperture size, and LED flash (12).

Participant Recruitment: We recruited patients with type 2 diabetes mellitus from the Puskesmas Banguntapan 2. A total of thirty-five participants performed a self-administered six-minute walk test bringing a smartphone in their hands. Four participants conducted the test simultaneously on four linear courses defined by two cones set 30 m apart in a field in front of the clinic. Before the test, participants recorded their heart rate using the mobile application, and nurses measured participants' heart rate using a pulse oximeter. At the end of 6 minutes, participants measured their heart rate using the mobile applications, and the distance walked were automatically estimated by the mobile application. At the same time, nurses measured and recorded participants' heart rate using a pulse oximeter and participants' walking distance.

Data analysis: Pearson correlation analysis was performed to test the correlation of heart rate measurement using the smartphone application and pulse oximeter, and the correlation of distance estimated by the smartphone application and measured distance. The accuracy of the heart rate and distance walked measurement by the smartphone application were assessed by calculating mean absolute error and by visually inspecting the Bland-Altman Plot.

RESULTS AND DISCUSSION

Application-based heart rate measurement compared to pulse oximetry measurement. The correlation between heart rate measurement by the smartphone application and pulse oximetry was r=0.943 and r=0.953, respectively, for heart rate before the test and heart rate at the end of 6 minutes. The accuracy of the measurement of heart rate before the test and at the end of 6 minutes by the smartphone application compared to a pulse oximeter, reported as mean absolute error, were 4.14 ± 0.94 bpm and 4.46 ± 0.93 respectively. Moreover, the Bland-Altman plot showed a high level of agreement (Figure 1& Figure 2).

Figure 1. Heart rate before the 6MWT estimated by the application compared to the pulse oximetry

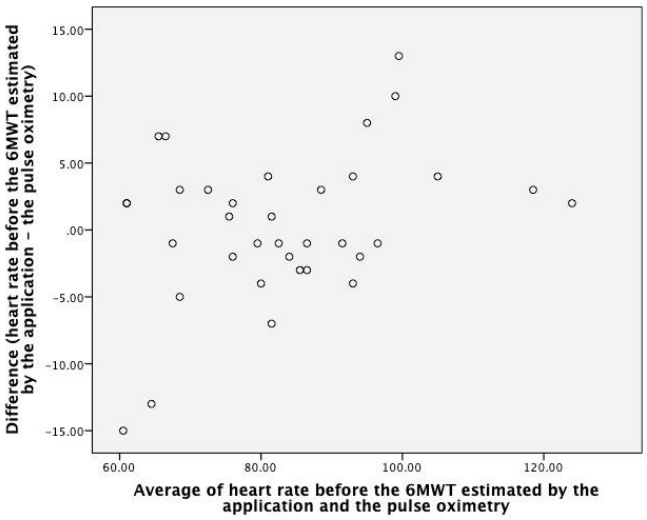
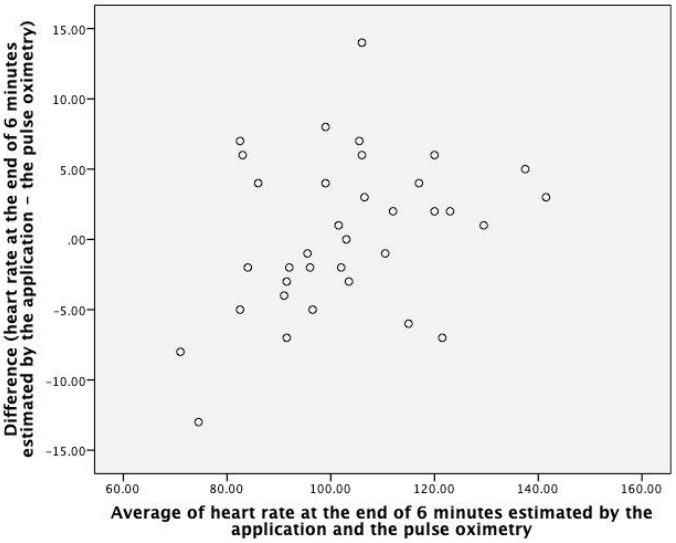


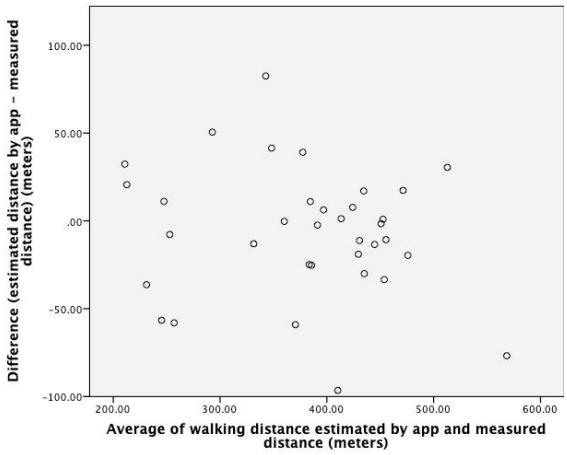
Figure 2. Heart rate at the end of 6 minutes estimated by the application compared to the pulse oximetry



3.2. Application-based walking distance measurement compared to the measured distance

The walking distance estimated by the smartphone application was highly correlated (r=0.898) and showed a high agreement with the measured distance (Figure 3). The walking distance measurement by the smartphone application resulted in a mean absolute error of 27.58 ± 6.20 meters.

Fig. 3: Walking distance estimated by the application compared to the measured distance



DISCUSSION

We have demonstrated that a smartphone application with heart rate measurement and walking distance estimation functions may have very good accuracy for self-assessment of cardiorespiratory fitness among patients with type 2 diabetes mellitus. Embedded with the two functions, the smartphone application still has comparable accuracy to the application with heart rate measurement only[11] or walking distance measurement only [10]. While skin conditions could affect the accuracy of heart rate measurement by photoplethysmography[13], our findings suggested that photoplethysmography could accurately measure the heart rate of patients with type 2 diabetes mellitus whom the majority have altered skin conditions[14]. Previous studies suggested an excellent accuracy of iOS-based smartphone applications in measuring heart rate measurement among healthy adults[11]. Our results add to evidence that an Android-based smartphone application can accurately measure heart rate among patients with type 2 diabetes mellitus. Our study also showed that an Android-based smartphone application has comparable accuracy to iOS-based applications in estimating the walking distance of a 6MWT[10]. Since the majority of Indonesians use Android-based smartphones[15], an Android-based smartphone application may be useful for self-assessment of cardiorespiratory fitness among patients with type 2 diabetes mellitus in Indonesia.

CONCLUSION

The Inafit, an Android-based smartphone application accurately estimates the heart rate before the test, heart rate at the end of 6 minutes, and walking distance among patients with type 2 diabetes mellitus performing a 6MWT. Thus, a mobile application may be suitable for self-assessment of cardiorespiratory fitness among patients with type 2 diabetes mellitus.

REFERENCES

1. American Diabetes Association. “1. Improving Care and Promoting Health in Populations: Standards of Medical Care in Diabetes—2019.” *Diabetes Care*, vol. 42, no. Supplement 1, 2019, pp. S7–S12.
2. Clement, Maureen, et al. “Organization of Diabetes Care.” *Canadian Journal of Diabetes*, 42 Suppl 1, 2018, pp. S27–S35.
3. Rudijanto, Achmad, et al. *Konsensus Pengelolaan Dan Pencegahan Diabetes Melitus Tipe 2 Di Indonesia 2015*. Jakarta, Indonesia: PB Perkeni ; 2015.
4. Umpierre, Daniel, et al. “Physical Activity Advice Only or Structured Exercise Training and Association with HbA1c Levels in Type 2 Diabetes: A Systematic Review and Meta-Analysis.” *JAMA*, vol. 305, no. 17, 2011, pp. 1790–1799.
5. Ary, D V, et al. “Patient Perspective on Factors Contributing to Nonadherence to Diabetes Regimen.” *Diabetes Care*, vol. 9, no. 2, 1986, pp. 168–172.
6. O’hagan, Ciara, et al. “Exercise Prescription in the Treatment of Type 2 Diabetes Mellitus: Current Practices, Existing Guidelines and Future Directions.” *Sports Medicine*, vol. 43, no. 1, 2013, pp. 39–49.
7. Ross, et al. “Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association.” *Circulation*, vol. 134, no. 24, 2016, pp. e653–e699.
8. American Thoracic Society. ATS Statement: Guidelines for the Six-Minute Walk Test.” *American Journal of Respiratory and Critical Care Medicine*, vol. 166, no. 1, 2002, pp. 111–117.
9. Mänttäri, Ari, et al. “Six-Minute Walk Test: a Tool for Predicting Maximal Aerobic Power (VO2 Max) in Healthy Adults.” *Clinical Physiology and Functional Imaging*, vol. 38, no. 6, 2018, pp. 1038–1045.
10. Brooks, Gabriel C, et al. “Accuracy and Usability of a Self-Administered 6-Minute Walk Test Smartphone Application.” *Circulation. Heart Failure*, vol. 8, no. 5, 2015, pp. 905–13.
11. Coppetti, Thomas, et al. “Accuracy of Smartphone Apps for Heart Rate Measurement.” *European Journal of Preventive Cardiology*, vol. 24, no. 12, 2017, pp. 1287–1293.
12. Xiaomi Redmi Note 4 - Full phone specifications. GSM Arena. https://www.gsmarena.com/xiaomi_redmi_note_4-8531.php. Accessed October 5, 2019.
13. Lemay, Mathieu, et al. “Chapter 2.3 - Application of Optical Heart Rate Monitoring.” *Wearable Sensors: Fundamentals, Implementation and Applications*, Academic Press, 2014, pp. 105–129.
14. Duff, Michelle, et al. “Cutaneous Manifestations of Diabetes Mellitus.” *Clinical Diabetes : a Publication of the American Diabetes Association*, vol. 33, no. 1, 2015, pp. 40–8.
15. “Mobile Operating System Market Share Indonesia.” *StatCounter Global Stats*, https://gs.statcounter.com/os-market-share/mobile/indonesia.