Evaluation of the usefulness of smartphone-directed applications for measuring heart rate and arrhythmia detection

Ocena przydatności aplikacji na smartfony do pomiaru częstości rytmu serca i detekcji arytmii

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Summary

Introduction: There are many available applications for smartphones to measure heart rate (HR) based on a finger pulse wave, without any additional devices. An important feature of the application should be the possibility to detect arrhythmia, especially atrial fibrillation (AF). The purpose of this study was to evaluate the utility of HR measurement applications, available for smartphones, in terms of the reliability of the measurements and the possibilities for arrhythmia detection.

Material/Methods: From the free applications available on smartphones with the iOS operating system we selected all (N=16), which offer HR measurement and a simultaneous graphical pulse wave recording. The HR was examined in 15 healthy volunteers with a sinus rhythm confirmed in ECG. The next step was to evaluate the reliability of HR measurement in 15 patients with AF.

Results: The average difference in the HR was 6% (0.6%-33%), while a difference below 5% was observed in 11 applications. According to our study, the most reliable applications to measure HR in patients with sinus rhythm was Instant Heart Rate by Azumio company. Five most reliable applications have been selected to test in patients with AF. We have chosen this application according to the most reliable HR measurement (<5%), best graphic pulse wave recording and the ability to view the recording at the end of the measurement. Only 1 of 5 applications - Heart Rate from Bump company - had >95% HR compatibility with ECG (the measurement difference was 0.88 %).

Conclusions: The majority of the free applications, available for smartphones, are able to measure HR precisely in patients with sinus rhythm, while in patients with AF, the exact measurement is significantly impeded by HR deficits. Only one out of 16 applications was able to measure HR in a patient with AF. None of the available applications could detect AF.

Keywords: **Atrial fibrillation • Arrhythmia • Smartphone application • heart rate • HR**

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Background

The rapid development of mobile telephone and mobile technology opens up new, previously unknown, horizons in twenty-first century medicine. It has been estimated that the number of people using smartphones will be about 3.5 billion in 2019 [3]. Mobile devices have become extremely attractive due to their simplicity and huge development potential. It is well known that they are constantly expanding their use in increasingly modern devices that are able to monitor our health. Currently, they can monitor heart rate, blood pressure, body weight, fetal rhythm or even uterine muscle tension in a pregnant woman [5,8]. Due to its low cost, wireless communication and non-invasive capabilities are increasingly being used in medicine. Measurements are made with special sensors built in mobile devices or small adapters that extend the capabilities of mobile devices. The goal of mobile applications in medicine is to extend existing health care with the simple steps that you can perform yourself in your home [1].

Currently, there are a lot of commonly available smartphone applications for measuring heart rate (HR). Many of them use mobile technology built into the camera in a way that does not require any additional equipment. They operate on built-in sensors and integrate them into a mobile application that installs on Android, iOS, or Windows. The essential function of such applications would be the possibility of detecting some arrhythmias - especially atrial fibrillation (AF).

AF is the most common arrhythmia in adults. The average age of patients with this condition is 75-85, with a steady increase in the average age of patients [4]. AF is a disease that is often asymptomatic, making it difficult to diagnose [4]. This arrhythmia increases an almost 5-fold risk of a stroke and a 3-fold risk of congestive heart failure. It also involves higher overall mortality in this group of patients. AF patients are significantly more likely to be hospitalized than those without arrhythmia. It is believed that AF is a major challenge in the treatment of cardiovascular disease in modern society [5]. Mobile applications for early AF detection would be a very valuable screening test for this arrhythmia.

The main aim of this study was to assess the suitability of free HR measuring applications for smartphones with iOS in terms of the reliability of measurements and the ability to detect arrhythmias.

Methods

From the available free iOS applications we selected thos (N = 16) that offer HR measurements, while graphically displaying pulse waveform [Figure 1]. These HR applications use a camera built-in smartphone that emits a light wave to read the pulse wave from your finger.

Of the selected applications, 56% (9/16) offered the possibility to measure the HR, and in 44% (7/16) the measurement time was in the range of 10-30s. We also noticed the graphic recording of the pulse wave during measurement. Half of the studied applications (50%, 8/16) represent 5 or more bits during measurement.

It was also important to see the waveform record after the measurement. Half (8/16) of the application offered

Fig. 1. Graphical representation of all tested applications on iOS (N = 16) phones that offer HR measurement with simultaneous graphic representation of pulse waveform

such a function, but only 13% (2/16) could see the entire record. The exact specification of all applications is shown in Table 1.

The study was divided into two parts:

- HR measurement in healthy volunteers with sinus rhythm.
- HR measurement in patients with persistent or fixed AF.

The first part of the study assessed the HR compliance measured by the ECG-HR application in 15 healthy non-smokers (8 women, 7 men, age 20-35). The test was performed in a lying position with the right index finger placed on the lens of the camera.

ECG electrodes were connected in a standard configuration. Volunteers had not been drinking coffee or alcohol for 2 hours before the study and were after 5 minutes of rest. Everyone assessed HR using mobile applications and simultaneously recorded 12 lead ECGs to assess HR and rhythm. Each person's measurement was conducted 3 times. The study was conducted using the iPhone 5S smartphone. The second part of the study consisted of assessing the HR compliance measured by ECG-based

HR measurement in 15 patients with persistent AF (11 women, 9 men, age 49-78). Only 5 applications (marked red in the table) with the most reliable HR measurement, the best visual waveform record and the ability to view this record after registration were selected for the second part of the study.

For statistical analysis Stata®/Special Edition 14 (StataCorp LP, College Station, Texas, USA) was used.

Results

The average difference between HR measurements using mobile applications and 12-lead ECG in sinus patients was 6% (0.6% -33%). A difference of <5% was observed in 11 applications (69%) marked with a star in Table 2. Azumio by Instant HeartRate was considered the most reliable application in sinus rhythm patients. It was characterized not only by the excellent 98% accuracy, but also by the continuous waveform recording and the recording of the entire record. All the measurements and the percentage of compliance are shown in Table 2.

The next step was to assess the reliability of HR measurements in patients with AF. For the test, 5 best-rated

Table 1. Application Specification (N = 16)

Name	Brand	Recording time [s]	Visible numer of bites	cording
Cardiio - HeartRate monitor	Cardiio, Inc.	continuous	all	partly
Free visual heart rate monitor	Acrossair	continuous	3	-
Heart Beat Rate - Heart Rate Monitor	Bio2imaging	25	7	5 bites
Heart Rate – free	CMG Research Ltd	continuous	all	partly
Runtastic Heart Rate Monitor	Runtastic	10	5	-
Optical Heart Rate Monitor	Jian Lin	continuous	4	4 bites
HeartRate	Bump Networks Inc.	10	4	4 bites
Instant Heart Rate - Heart rate monitor	Azumio Inc.	continuous	4	all
Free Heart Rate - Heart Rate Monitor	Ellisapps Inc.	10	4	6 bites
My pulse by I.C.E.	Akers Media Group, Inc.	10	5	-
MyPulse lite - Instant Heart Rate	Tingalin, LLC	continuous	all	-
Nabdat HeartRate Monitor	Startappz	15	1	-
Renault Pulse App - Powered by Passion	Vehicle Distributors Australia Pty Ltd.	continuous	3	-
Pulse-o-matic	ShuNingBian	continuous	5	-
PulseRatePro	EarthBrowser	continuous	all	all
Heart Fitness	Senscare	30	4	-

No recording

Table 2. Differences and percentage of compatibility achieved in all applications

Name	compatibility [%]	Compatibility >95%	to AF test	difference [%]	compatibility [%]
Cardiio - HeartRate monitor *	98	Yes	Yes	14	86
Free visual heart rate monitor *	95	No			
Heart Beat Rate - Heart Rate Monitor *	96	Yes	Yes	x	X
HeartRate – free	80	No			
RuntasticHeartRate Monitor *	99	Yes			
Optical HeartRate Monitor *	99	Yes	Yes	10	90
HeartRate *	96	Yes	Yes	1	99
Instant Heart Rate - Heart rate monitor *	98	Yes	Yes	x	X
Free Heart Rate - Heart Rate Monitor	85	No			
my pulse by I.C.E.	93	No			
myPulse lite - Instant Heart Rate *	98	Yes			
NabdatHeartRate Monitor *	98	Yes			
Renault Pulse App - Powered by Passion *	99	Yes			
Pulse-o-matic *	98	Yes			
PulseRatePro	67	No			
Heart Fitness *	96	Yes			

AF- atrial fibrillation, x-no pulse reading

applications were selected from the first part of the test (marked in red). All measurements and the percentage of compliance are shown in Table 2. It was observed that the most reliable HR measurement application in AF patients was Heartrate by Bump Networks - HR measurement accuracy> 95% (0.88% difference in measurement). It could measure HR in an an AF patient. Two other applications, Instant HeartRate and HeartRate Beat, fail to read AF, but suggested that something is wrong with the pulse and that you should see a doctor. The biggest disadvantage of this application is the ability to record and play only the last 4 bits of the record.

This study shows that heart rate deficits when measuring HR significantly impeded or prevented applications from measuring AF. Unfortunately, free iOS smartphone applications did not offer the ability to detect arrhythmia based on heart rate recordings using the built-in camera.

DISCUSSION

Nowadays, medicine increasingly uses modern ICT tools, combining patient needs and technical progress, beyond the barriers of traditional health care systems. Every

year, the number of mobile applications that enable HR measurement is increasing.

It turns out that, with the enormous amount of free applications, only some measure HR reliably enough. This is undoubtedly extremely useful in people with tachycardia or bradycardia, diseases which are not accompanied by any symptoms. The compliance of HR measurement in healthy subjects using mobile applications has been confirmed in numerous works, including In Schäfer et al. [6] or Penga et al. [7]. The authors have observed high compatibility measurements using mobile devices and single-channel ECGs. These results are consistent with the data obtained in this study. According to our observations, mobile applications worth recommending, with a reliability of> 95% are: Cardio-Heart Rate Monitor, Heart Beat Rate Monitor, Heart Rate Monitor, Heart Rate Monitor, Heart Rate Monitor, MyPulse lite - Instant Heart Rate, Nabdat Heart Rate Monitor, Renault Pulse App - Powered by Passion, Pulse-o-matic, Heart Fitness.

Complications in the above applications occur when a patient has an irregular heartbeat that generates arrhythmias. Applications are not able to read HR or

the result is false. Unfortunately, there is currently no work assessing the credibility of mobile applications in people with AF. Most available publications evaluate healthy volunteers. The only study of patients with heart diseases is a study by Ho et al. [4]. 40 children with cardiovascular disease, with a median age of 4.3 years, were evaluated. The authors describe compatibility in HR measurement using mobile applications and ECG in children with HR up to 120 bpm. In the case of tachycardia of higher values, the compatibility was at the level of 65%. It is worth noting that in the study group there were no patients with arrhythmias. The ability to detect tachycardia and sinus bradycardia is a huge advantage of these applications. Thanks to this function, it is possible to detect many diseases, not just cardiovascular ones, which manifest themselves as or slowed higher or lower HR. Early detection of accelerated cardiac action may prevent cardiomyopathy. This initially leads to atrial dilatation and then to similar changes in the ventricles, especially the left. This is accompanied by a decrease in the EF and symptoms of left ventricular failure. This is a state that can be reversible, so early diagnosis is very important. The best examples of other diseases that manifest as tachycardia are thyroid disease, anemia, or electrolyte abnormalities.

In addition, long-term acceleration and HR release are associated with greater cardiovascular risk. As high compliance with HR measurements in healthy individuals was observed, it is certainly a challenge for the future of mobile paid applications to extend their detection capabilities to arrhythmia detection. This would be an extremely valuable tool in patients with paroxysmal arrhythmias in daily clinical practice. Early detection of AF can significantly reduce the number of thromboembolic complications in this group of patients. Currently, when a mobile device are not able to measure HR or measurements are unlikely, it should inform the patient that a more advanced heart rate and rhythm evaluation should be performed. The solution for patients with arrhythmias can be a mobile application (ECGCheck or KardiaAliveCor), which requires additional equipment such as a single lead ECG recorder. The sensor is equipped with two electrodes, which are applied to the index fingers of both hands of the patient. Working with a suitable application shows the result of a 30s single-repository ECG. It allows basic diagnostics of the cardiac conduction system and symptoms resulting from arrhythmias. The result can be sent electronically to your doctor in a simple and immediate way.

The AliveCor application offers AF detection and is registered by the Food and Drug Administration (FDA) and is CE certified (ConformitéEuropéenne) [9]. There are also pulse rate belts available by Suunto company. These belts send information about the heartbeat to compatible products of this company using ANT transmission technology, providing a precise measurement. They are effective and accurate during physical exercise in people with sinus rhythm. Their ability to detect arrhythmias is unfortunately minimal.

Smartphones are present in our daily lives, and advances in technology make them increasingly helpful in screening and detecting rhythm disorders. The higher the progress of the application, the more functions they offer. Over the years we have observed that more and more functions are being developed and refined in the standard version. New technical solutions and the right approach for developers to create easy-to-use applications make telemedicine even easier for the elderly to significantly change the health care model in the future.

Conclusion

The majority of free apps available for iOS smartphones can reliably measure HR in patients with sinus rhythm, while in patients with AF, the measurement is significantly impeded by heart rate deficits. Only one application was able to measure HR in an AF patient, but none was able to detect arrhythmia. The goal for the future is to create applications that enable the detection of life-threatening arrhythmias including AF.

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