Original paper

The smartphone as an instrument for blood pressure measurement

Wykorzystanie telefonu komórkowego do pomiaru ciśnienia tętniczego

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Słowa kluczowe: ciśnienie krwi, telefon komórkowy, telemedycyna.

Abstract

Introduction: Number of population suffering from hypertension is increasing. So that, monitoring of this phenomenon should concentrate attention of medical industry, and receive high priority. One of the recommended procedure in hypertension treatment, and control is home blood pressure monitoring, which can be tested using smartphone application.
Aim of the research: To evaluate the feasibility of a new blood pressure (BP) measurement tool – a smartphone application.
Material and methods: The study included 50 subjects with the diagnosis of hypertension. Blood pressure measurement was tested in the following conditions: using a sphygmomanometer and using a smartphone by a specialist, and using a smartphone by the patient him/herself. The total number of results that differed from the measurement performed by the specialist by more than 5 mm Hg, and by 10% or more, was counted.
Results: Mean results of systolic and diastolic BP did not differ significantly between measurements done by a specialist using a sphygmomanometer and those done using a smartphone application. There were 82% of results of systolic and 92% of diastolic BP that differed from Korotkoff sound technique in a range greater than 5 mm Hg and 36% in systolic and 86% in diastolic BP by 10% or more.
Conclusions: The tested application should not yet be used for BP monitoring.

Streszczenie

Wprowadzenie: Liczba pacjentów z nadciśnieniem stale wzrasta, dlatego monitorowanie tego zjawiska powinno skupiać uwagę środowiska medycznego. Jedną z rekomendacji w nadciśnieniu są domowe pomiary ciśnienia krwi, do których można również wykorzystać telefon komórkowy.
Cel pracy: Przedstawienie użyteczności aplikacji na telefon komórkowy jako narzędzia do pomiaru ciśnienia krwi.
Materiał i metody: W badaniu wzięło udział 50 chorych ze zdiagnozowanym nadciśnieniem. Pomiaru dokonał specjalista, używając tradycyjnego aparatu do pomiaru ciśnienia krwi, a następnie aplikacji na telefon komórkowy. Później pacjent samodzielnie mierzył ciśnienie przy użyciu aplikacji. Przedstawiono liczbę pomiarów wykonanych przy użyciu telefonu komórkowego, które różniły się od tradycyjnego pomiaru przez specjalistę o więcej niż 5 mm Hg oraz o więcej niż 10%.
Wyniki: Średnie wyniki skurczowego i rozkurczowego ciśnienia krwi zmierzonego przez specjalistę nie różniły się w zależności od zastosowanej techniki pomiaru. W indywidualnej analizie każdego pomiaru zaobserwowano natomiast różnicę 82% wyników skurczowego i 92% wyników rozkurczowego ciśnienia krwi różniącego się o więcej niż 5 mm Hg zmierzonego przez specjalistę przy użyciu tradycyjnej metody i telefonu komórkowego. Wyniki skurczowego i rozkurczowego ciśnienia w zależności od metody pomiaru różniły się o 10% i więcej w przypadku 36% pomiarów ciśnienia skurczowego i 86% pomiarów ciśnienia rozkurczowego.
Wnioski: Testowana aplikacja nie powinna być stosowana do monitorowania ciśnienia krwi.

Introduction

Smartphones are transforming culture, social life, technology, and other diverse aspects of modern society [1]. Medicine is also experiencing the growing impact of the mobile phone industry [2–5]. Use of smartphones and specially design medical applications (apps) could have potential benefits for healthcare [4, 6]. The smartphone could be an ideal monitoring tool

for physicians because patients could be tested anywhere at any time and in any circumstances [7].

In daily clinical practice the authors of this report were asked by patients with hypertension about the possibility of using a smartphone app to perform blood pressure (BP) measurements in the home environment. To date, the authors of this report did not find any studies that could provide an answer to such questions.

Research in this field is important inter alia because of the fact that in clinical medicine BP measurements are considered to be one of the most important [8]. Monitoring of BP in the home environment has potential benefit in the management of hypertension [9], which affects nearly one billion people or ~26% of the adult population of the world [10]. The number of adults suffering from hypertension is predicted to increase, so prevention, detection, treatment, and control of this issue should receive high priority [10]. Hypertension among patients from the United States (U.S.) is listed as a primary or contributing cause in ~15% of the 2.4 million deaths that occurred in 2009 [11]. Annual costs directly attributable to hypertension are projected to increase to $130.4 billion in 2030 [12]. It is predicted that the use of home BP monitoring for hypertension diagnosis would result in a saving of billions dollars in hypertension-related medical costs [13]. That is why, among other aspects, self BP monitoring has been recommended by experts and international guidelines as an adjunct to office BP monitoring for the management of hypertension [14]. Screening for high blood pressure was also recommended in adults by the U.S. Preventive Services Task Force (grade A recommendation) [15].

Aim of the research

That is why the aim of this study was to evaluate the feasibility of blood pressure measurement done by smartphone application (Real Blood Pressure Calc® by PurePush) in the group of patients with hypertension compared with testing done by a trained health care provider according to American Heart Association (AHA) recommendations [8].

Material and methods

The study included 50 patients hospitalised in a cardiology department. All participants had the diagnosis of hypertension and were under antihypertensive-medication control. The study protocol was approved by the Local Ethics Committee. Traditional BP measurement using a sphygmomanometer and the Korotkoff sound technique was done by a trained health care provider according to AHA guidelines as a standard clinical procedure [8].

Before and after the traditional procedure, authors tested BP using the Real Blood Pressure Calc by PurePush smartphone application. The patient's position was based on the AHA BP measurement guidelines [8]. The procedure of phone BP testing was based on the guidelines provided by the provider of the application, and included: pressing the smartphone camera lens gently with the index finger of the right hand, and pressing the index finger of the left hand on the phone screen in a marked area. After 10 s of measurement the results were read. The patients were blinded to the results obtained by the healthcare provider until they had tested their BP by themselves.

Procedures

The BP measurement was performed in the following order:
- BP measurement using smartphone by a trained healthcare provider;
- BP measurement using a sphygmomanometer by a trained healthcare provider;
- BP measurement using a smartphone by the patient him/herself.

Patients rested for 10 min while the procedure was explained to them.

Loud and clear instructions were given on how the test should be conducted and what the patient should do. These instructions included the following information: hold still, cover the camera lens with your fingertip, press gently on the camera.

Statistical analysis

Normality was assessed using the Shapiro-Wilks test. Student's t test was used when the data were normally distributed and the Mann-Whitney *U* test was used for other comparisons. A significance level of $p < 0.05$ was chosen for overall effects. We performed the following comparisons:
- results derived from the smartphone app versus results obtained using a sphygmomanometer (both measurements were conducted by a trained healthcare provider);
- results derived from the smartphone app, conducted by trained healthcare provider, versus results from the smartphone app performed by the patient him/herself.

The total number of results that differed from the measurement performed by the specialist by more than 5 mm Hg, and by 10% or more, was additionally recorded.

Results

Mean results for systolic (SBP) and diastolic (DBP) blood pressure measurement are presented in Table 1.

The authors evaluated the difference between the results in a different condition of measurement. The results were divided according to the context of measurement. Summary of statistical significance (*p*-val-

Table 1. Mean results of systolic and diastolic blood pressure (BP)

Variable	Systolic BP	Diastolic BP
Traditional measurement	117 ±17.3	72 ±11.5
Smartphone measurement by healthcare provider	117 ±16	72 ±14.3
Smartphone measurement by patient him/herself	125 ±12.1	80 ±7.7

ue) for both systolic and diastolic BP in all conditions are show in Table 2.

The total number of results that differed from the measurement performed by the specialist by more than 5 mm Hg, and by 10% or more, was counted. A summary of this analysis is shown in Table 3.

Discussion

According to its potential advantages and the mean results presented in Table 1, smartphones could be a useful tool for BP monitoring. The mean results of both systolic and diastolic BP did not differ significantly between measurements done by healthcare provider in the traditional way and by smartphone app (Table 2). It is known that screening of BP in the population for detection of hypertension early, and initiation of treatment before the onset of target organ damage is highly cost effective [16, 17]. The rising popularity of smartphones could be helpful in BP screening in the population. However, further data analysis showed a poor level of accuracy in BP testing done by smartphone application in conditions other than those measured by a healthcare provider (Table 2). Such results indicate that at present screening of BP in the population using smartphones should not be done. Similarly, no significant agreement was observed in BP assessment done by a healthcare provider using a smartphone versus results from a smartphone used by the patient him/herself. More data (Table 3) demonstrate that the results of BP testing done by smartphone can be considered as incidental. The total amount of results deviating more than 5 mm Hg and by 10% or more from the measurement performed by the specialist is dumbfounding.

Exact measurement of BP is of paramount importance [16]. Underrating true blood pressure by 5 mm Hg would mislabel millions of individuals as having pre hypertension when true hypertension is actually present. For example, underestimation of the DBP by 5 mm Hg could result in more than 60% of hypertensive individuals being denied potentially lifesaving treatment, while the number of persons diagnosed with hypertension would more than double if SBP were over estimated by 5 mm Hg [16, 18–21]. Data presented in Table 3 indicate that regardless of the type of comparison there are a number of results that differ from the Korotkoff sound technique results in a range greater than 5 mm Hg. This result indicates that there is a chance of getting a result similar to the professional measurement; however, the differences observed in many cases (Table 3), in the authors' opinion, do not allow the results obtained by smartphone to qualify as an acceptable outcome.

Table 2. Statistical significance

Blood pressure	Traditional measurement vs. smartphone measurement by healthcare provider (*p*-value)	Smartphone measurement by healthcare provider vs. smartphone measurement by patient him/herself (*p*-value)	Traditional measurement vs. smartphone measurement by patient him/herself (*p*-value)
Systolic	0.8999	0.0069	0.0147
Diastolic	1.0000	0.0005	< 0.0001

Table 3. Total number of results that differed from the measurement performed by the specialist using a sphygmomanometer by more than 5 mm Hg, and by 10% or more

Blood pressure	Traditional measurement vs. smartphone measurement by healthcare provider	Smartphone measurement by health care provider vs. smartphone measurement by patient him/herself	Traditional measurement vs. smartphone measurement by patient him/herself
Number of measurement where the difference was greater than 5 mm Hg:			
Systolic	41 (82%)	43 (86%)	35 (70%)
Diastolic	46 (92%)	40 (80%)	36 (72%)
Number of measurements where the difference was greater than 10%:			
Systolic	18 (36%)	30 (60%)	34 (68%)
Diastolic	43 (86%)	35 (70%)	31 (62%)

The producer of the tested application states that the app calculates blood pressure with approximately ±10% accuracy. Our results (Table 3) indicate that not all results are within this range. Measurements done both by healthcare provider and the patient him/herself demonstrate a large number (36% to 86%) of results that were not within the range that the producer of the application stated.

Guidelines and experts are unanimous about the statement that only devices that have passed adequate validation tests, referring to standard protocols, should be used and recommended [8]. The tested app calculates BP on the basis of brightness of the skin over time captured by a camera lens. The algorithms used for the calculation of BP measurement have not been published by the provider of the application, making it impossible to understand the basis of the BP results, or to have a point of discussion about the essence of the idea of the app author, and about the results of any testing. There is also no publication on this topic so far. We searched the Medline database using the keywords: blood pressure, phone, smartphone, and application, and no research referring to this topic was identified. The lack of reliable information and inconclusive results of this study give the authors concern about the many random comments of appreciation found on the application webpage (examples: Glenn Felton Jr: "Excellent I can now track with accuracy…", Krishna Kumar Tiwari: "Nice & useful. Works great", Rolando Hernandez: "Awesome. Works"). The popularity of medical designed apps is still growing [3, 4, 6]. "Real Blood Pressure Calc® by PurePush" used in the present study has been downloaded and installed from the manufacturer's worldwide webpage somewhere in the range 1,000,000 to 5,000,000 times. The authors of this report think that inaccurate results and misleading information about the state of patients' health can have adverse effect on patients' health condition. There are a lot of potential threats resulting from the clearly false or misleading results generated from the tested application. It is generally known that BP is a predictor of cardiovascular events [22, 23]. Misdiagnosis of hypertension, beyond the patient's mental burden, may lead to unnecessary initiation of a medical visit and treatment. Showing significant prognostic value [23], monitoring of BP is recommended by the American Heart Association to determine whether treatments are working properly [8]. Correct BP observed during subsequent home testing can be regarded as an expression of the effectiveness of treatment, confirming its validity. In turn, unrecognised hypertension can lead to discontinuation of proper treatment and consequently to complications in the cardiovascular system [24].

According to the results of this report and the well-established position of self-monitoring of BP and its potential for prevention of white collar and masked hypertension [25], the authors conclude that during routine visits, patients should be asked about the source of any BP results brought into the medical doctor's office. Moreover, patients and physicians should be warned and be aware of possible inaccurate measures from smartphone apps for home BP measurement in hypertension management or screening of blood pressure. The authors of this report also think that regulation and guidance for health-related apps are necessary if the use of mobile technology for assessing health condition is to be safe. Summing up, according to the presented results, the authors of this publication think that smartphone apps should not be used for the control of blood pressure in the group of patients with hypertension and for screening of blood pressure in the general population as yet. Future research should be done in the field of testing the validity of other unverified blood pressure smartphone applications.

Conclusions

The smartphone application tested in this study should not be used for blood pressure monitoring as yet due to the high range of measurement error observed in this study.

Conflicts of interest

The authors declare no conflict of interest.

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