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PREVENTION OF HYPERTENSION: PUBLIC HEALTH CHALLENGES (Y YANO, SECTION EDITOR)

How Digital Health Can Be Applied for Preventing and Managing Hypertension

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Abstract

Purpose of Review To summarize available data on digital health strategies for the prevention and management of hypertension, discussing the state-of-the-art, current limitations, and future perspective of this approach.

Recent Findings Technology is developing at a fast pace and is providing a number of novel solutions for cardiovascular patients, in particular in the field of digital health. Even if the benefit of these approaches is intuitive, the methodological heterogeneity of the available studies and their small sample size have made it difficult to provide robust evidence regarding the usefulness and cost-effectiveness of digital health technologies. Recently, studies with larger sample sizes and some meta-analyses have provided more convincing data on the favorable impact of such strategies.

Summary Digital health solutions may offer a chance to improve primary prevention and for timely diagnosis and effective management of hypertension. Results from small studies are promising, but there is a strong need for larger, long-term, and well-designed clinical trials to make these novel solutions really applicable in real-life patients' care.

Keywords Telemedicine · Digital health · Hypertension prevention · Medical technology · eHealth

Introduction

Hypertension is one of the main cardiovascular risk factors and is responsible for 10.7 million deaths and 211.8 million disability-adjusted life-years (DALYs) in 2015, with a 50% increase over the corresponding 1990 estimates [1•]. It has been estimated that one billion people have hypertension, and the number will increase up to 1.5 billion in 2025 [2] (Fig. 1).

In spite of all the efforts made to prevent, timely diagnose, and effectively manage arterial hypertension, its incidence is increasing and blood pressure control in affected individuals is still unsatisfactory. This is due to many factors, as highlighted by the 2013 ESH/ESC guidelines on hypertension [3•], including (1) patients' poor adherence to medical indications, (2) physicians' inertia in keeping up-to-date with new recommendations and guidelines, and (3) insufficient healthcare systems.

Patients' poor compliance with physician's prescriptions can be explained by the fact that arterial hypertension is an asymptomatic condition, which delays diagnosis and makes it difficult for an individual to accept lifestyle changes and drug therapy. In fact, unhealthy lifestyle habits, and especially sedentariness, overweight, smoking, and a high-fat and high-salt diet, are known to play a major role in the development and maintenance of hypertension and in increasing cardiovascular risk in general [4].

Another critical issue is the difficulty experienced by doctors in applying the latest recommendations issued by leading scientific societies to perform a comprehensive evaluation of clinical parameters and pre-existing comorbidities, and to reliably assess and manage overall cardiovascular risk.

Finally, national healthcare systems need to revise their current approach to prevention of cardiovascular diseases and to management of chronic conditions, especially in the

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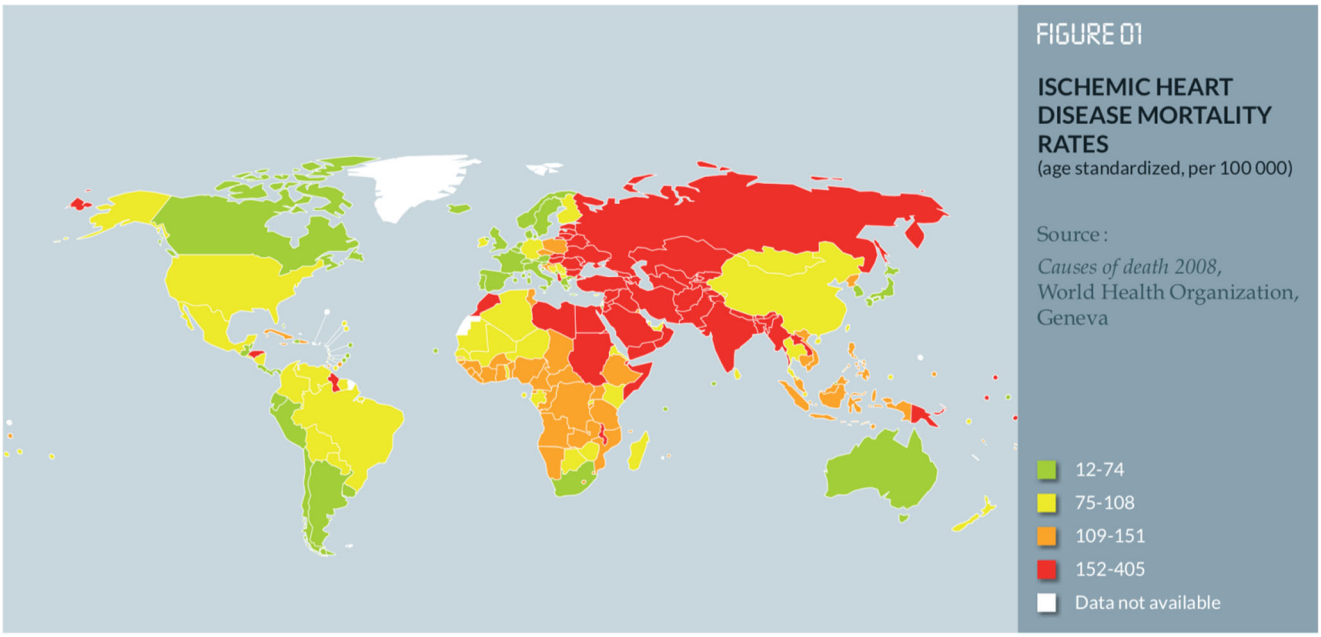

Fig. 1 Ischemic heart disease mortality rate. Complications of hypertension account for one-third of the cardiovascular deaths per year. Hypertension is responsible for at least 45% of deaths due to heart disease and 51% of deaths due to stroke (reprinted with permission from reference [2])

light of the prolongation of life expectancy, which corresponds to an increased number of elderly people living with disability and disease who need to be assisted with a tailored strategy. For such a strategy, the traditional healthcare approach is not sustainable, either from an economical or from a management point of view [3•].

On such a background, recent information and communication technology developments can help, in many different ways [5•]. Digital health tools can be designed to support both healthcare personnel and patients and may offer a wide range of functions which can be useful in this context. For example, digital health tools can facilitate patient–doctor relationship, by offering an easy approach to health data recording, storage, and transmission. Furthermore, they can represent easy-to-apply educational tools, designed to motivate doctors to stay up-to-date in their medical education, and to inform patients about their condition, with the final aim of ensuring a better compliance with medical prescriptions. This kind of strategy is particularly suitable for primary prevention of cardiovascular diseases and for management of chronic conditions; all possibilities that in the recent years have been explored [5•].

The aim of this review is in particular to summarize the currently available evidence about digital health strategies and their role in the prevention and management of hypertension.

Digital Health: Definition, Pros, and Cons

Digital or electronic health (eHealth) has been defined as the "use of information and communication technologies (ICT) for health" [6]. It exploits techniques and advances concepts emerging from different scientific domains, including computer science, electrical and biomedical engineering, medicine, and health-related sciences. A number of subtopics have been also identified, for example mobile health (mHealth) [7, 8] which "covers medical and public health practice supported by mobile devices such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices," and telemedicine [9] which refers to "physical and psychological diagnosis and treatments at a distance, including telemonitoring of patients' functions."

Digital health, and especially mHealth, may allow reaching individuals in their daily life and easily connecting them with the healthcare professionals in charge. On such premises, it could thus help in promoting a healthy lifestyle and increasing patients' compliance to medical prescriptions, which leads to optimization in prevention and management of hypertension [7].

A number of specific benefits may be offered by mHealth. First, mHealth allows reaching a very high number of people at no or small extra cost, thanks to the wide diffusion of landlines, personal computers, and mobile devices. In fact, it has been estimated that 3.4 billion people owned a smartphone in 2016, irrespective of geographical or socioeconomical conditions, with a steadily growing trend. These very favorable characteristics have been identified in a recent document by WHO [7] as a major drive for mHealth diffusion both in high- and low-income countries, which are trying to cut costs and to boost access to healthcare, respectively.

Second, mobile devices may also be equipped with intrinsic sensors, such as accelerometers, and can be matched to

external devices such as wearable sensors. In this way, they may offer the possibility to constantly acquire information on physiological and medical parameters and individuals' lifestyle features and daily activities, as well as on environmental parameters relevant to population health, such as altitude, air temperature, or air pollution. The data so obtained can then be used to implement evidence-driven healthcare practice interventions, to record, store, and access big data in a research activity framework, and also to empower patients in caring of their clinical conditions, facilitating the access to and the understanding of their own health-related information.

Finally, digital health may represent an ideal tool to support patients in taking an active role in the management of their own health conditions, boosting their awareness and basic medical knowledge. This may be strengthened by the development of ad hoc interactive tools, such as mobile phone applications (form now on abbreviated as apps) that may provide continuous education in an easy and simple manner. This is likely to encourage subjects to better adhere to lifestyle modification and drug therapy prescribed by their physicians [9].

Digital health, like other novel healthcare strategies, may carry some threats that need to be carefully assessed and always kept in mind.

The most relevant issue is probably data protection and security. In fact, health-related data are considered even more sensitive than banking data and must thus be protected. For example, hacking or unwanted sharing with third parties represent violations of patients' privacy. A recent survey has shown that more than 40% of app users never cared about possible issues deriving from privacy flaws [10].

Another very relevant topic, although more specific for the case of mHealth, is the lack of control of the content of the apps, which is often accompanied by a comparable absence of proper scientific validation for some signal recording devices [11•]. In fact, the content of the vast majority of health-related applications for mobile devices has not been validated by any scientific entity, such as national or international scientific societies, nor is the reliability of the information a criterion to increase the positive scores of an app and to promote its climb in the list of first-displayed apps in the app stores. Indeed, a proper regulation and standardization of mHealth technologies is still missing, which may represent a potential threat to patients' health. A significant attempt to more properly address this issue has come from the US Food & Drug Administration (FDA), which has released guidance recommendations in February 2015 for the developers and distributors of health-related apps. With this document, the FDA has set the basis to enforce regulatory requirements over those apps that are designed to diagnose, treat, or prevent a medical condition [8].

Finally, some subgroups of digital health services are characterized by high setup and management costs including the cost of equipment and the cost of training health practitioners and patients to inform how to utilize them. Due to the lack of methodologically flawless, adequately powered, randomized clinical trials aimed at demonstrating the benefits of digital health, digital health services are currently poorly recognized by governments and rarely funded by national healthcare systems.

Applications of Digital Health to Hypertension: Prevention

Many digital health primary prevention strategies have been proposed and tested, aiming at different goals. In fact, hypertension is attributable to many other cardiovascular risk factors, including overweight and obesity, smoking, unhealthful eating and drinking, and sedentariness [1•]. Thus, hypertension primary prevention must touch all the aforementioned issues. All digital strategies in primary care are based on the assumption that patients spend only a few hours per year having direct interaction with their healthcare practitioners, but they spend something like 5000 waking hours per year engaged in activities that affect their health [12].

Digital-based primary prevention strategies can thus be described as technology-supported lifestyle behavioral interventions. All the digital health services reach patients through the Internet, e-mail, SMS, or other electronic means, thus engaging them in a wide range of activities, such as remote BP, medication, and behavior monitoring and eventually offering relevant education, counseling, and motivational support.

A meta-analysis by Widmer et al. [9] identified 39 digital health studies focused on CV disease reduction through improving cardiovascular risk factors (i.e., focusing on weight control, lipid and blood pressure control) on more than 23,000 patients. The main tested strategies were telemedicine approaches and web-, email-, telephone-, or SMS-based tools, either in a primary care, workplace, or living environment. The heterogeneity of sample characteristics, data collected, and outcome evaluated made it difficult to effectively compare those studies. Thus, Widmer et al. concluded that evidence of a positive effect on CV disease outcomes was not statistically significant (RR = 1.21 (95% CI, 0.58–2.54); $P = 0.61$; I2 = 15%), even if Framingham risk core improved significantly. Weight loss (− 3.35 lbs. (95%CI − 5.22 lbs., − 1.48 lbs), $P < 0.001$, $I^2 = 96\%$; Fig. 3) and systolic blood pressure (SBP) reduction (mean difference = − 2.12 mmHg (95% CI, − 4.15 mmHg, − 0.09 mmHg); $P = .04$; $I^2 = 100\%$) were present among primary prevention studies. However, the effect on SBP was no longer significant when the two studies were excluded from the analyses (mean difference = − 1.31 mmHg (95% CI, − 3.43 mmHg, 0.80 mmHg); $P = 0.22$; $I^2 = 100\%$) [9]. Thus, Weidmer et al. were able to support only in part the hypothesis that web-based, telemedicine, and SMS texting approaches are effective in controlling CV risk. A

more recent experience in the use of digital health to support lifestyle changes was reported from Habibovic et al. [13], who have recently initiated a clinical trial to evaluate the efficacy of their "Do Cardiac Health: Advanced New Generation Ecosystem" (Do CHANGE) ecosystem, which integrates new technologies into a behavior change intervention in order to change the unhealthy lifestyles of cardiac patients.

A most comprehensive analysis of the effectiveness and efficacy of mobile health strategies in improving CV risk factors and thus hypertension risk factors has been performed by the AHA [5•] and published in a recent consensus document. Firstly, they analyzed weight reduction and found that a number of different approaches, including mobile technologies (texting and smartphone applications), tablets, and interactive voice response (IVR) systems, have been tested, along with matched connected devices, including e-scales and wireless physical activity monitoring devices [14–17]. After reviewing the most relevant papers, the authors concluded that this kind of intervention can be useful, especially when personally tailored, in motivated people [18]. Also, digital health strategies have been proposed to stimulate an increase in physical activity, with a suggested superior efficacy when matched with wearable sensors able to track movement [19–22]. The authors favorably described the emerging evidence, indicating the usefulness of physical activity tracking devices, associated with group behavioral treatments, in producing a significantly larger weight loss than the use of either ICT devices or group treatment alone. Finally, the potentiality of digital health in supporting smoking cessation, the most preventable CV risk factor, has also been explored. The most relevant papers are dated within the last 10 years. Large, well-controlled studies have indeed shown that SMS-based programs may result in approximately double the abstinence rates as compared to minimal intervention control conditions. Unfortunately, the failure rate of these programs is high (≈ 90% of subjects fail to quit at 6 months), and the heterogeneity of effect across studies suggests that certain varieties of SMS interventions may work better than others and that the success rate is different in different populations [23–27]. Research in this field is currently continuing, with different attempts being made at finding the more effective strategy to implementing digital health among different smoking cessation strategies [25].

Applications of Digital Health to Hypertension: Management

The history of digital health strategies application to the management of hypertension is quite long [26]. One of the first and most successful examples is telemonitoring, in which home blood pressure monitoring (HBPM) has been combined with dedicated devices recording BP values and sending them to the clinician in charge, thus promoting a more effective link between patients and physicians [28, 29, 30•, 31•]. This strategy has been recommended by the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure as a complementary method in the management of hypertensive patients [32] and proved to be effective in reducing BP values and in fighting both physicians' inertia and patients' poor adherence to treatment [30•]. The many different telemonitoring systems available are characterized by different modalities of data collection (i.e., manual entry, wireless transmission, cable transmission), patient-to-healthcare professional transmission (telephone-based, Internet-based, etc.), presence of feedback, frequency of contact, and additional features (e.g., alarms to remind medication intake, BP measurements, etc.). More successful interventions are multimodal, require less technical skills from the patients, and provide them with a feedback.

The efficacy of telemonitoring has been demonstrated in a number of meta-analyses [9, 31•]. Omboni et al. evaluated up to 23 RCT with more than 7000 patients. Home BP monitoring was associated with a significantly larger reduction in both office and ambulatory BP as compared to usual care, with a mean office systolic (S) and diastolic (D) BP reductions of 4.7 and 2.5 mmHg larger in the telemonitoring group than in the control usual care group, thus resulting in a significantly larger BP normalization rate at office measurement ($P < 0.001$) (Fig. 2). Interestingly, the higher costs sustained by the telemonitoring group appeared to be entirely due to the cost of technological equipment and not to "medical costs." Unfortunately, the small sample size of many studies and the heterogeneity of study conditions made the comparison among their actual impact on hypertension management difficult [33, 34•, 35, 36].

The main limitations of the conventional telemonitoring strategy include requirement of advanced equipment and need of training patients and dedicated healthcare providers to utilize the technique. New, adequately powered, ongoing RCT will hopefully help better clarify the usefulness and, moreover, the cost-effectiveness of these approaches [34•].

A meta-analysis from Widmer et al. [9], including the data from secondary CVD prevention studies, suggested a favorable effect of digital heath strategies on CVD outcomes (RR = 0.60 (95% CI, 0.43–0.83); $P = 0.002$; $I^2 = 0\%$). However, no effect on body weight and systolic blood pressure was observed.

An example of innovative digital health strategy used to manage hypertensive subjects is offered by a paper of our group, from Albini et al. [37•]. In this study, an integrated ICT-based Patients Optimal Strategy for Treatment (POST) system including home BP monitoring teletransmission, a dedicated web-based platform for patients' management by

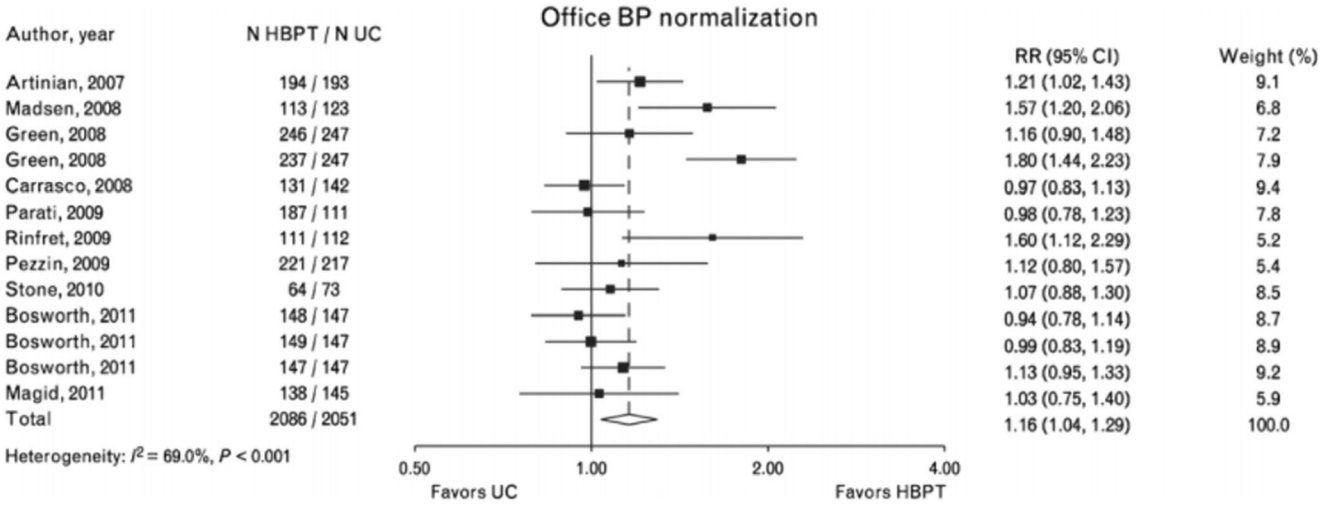

Fig. 2 Results from Omboni et al. [31•] meta-analysis on telemonitoring in hypertension. Relative risk (RR) of office blood pressure (BP) below target (i.e., normalization) at the end of the study in the home blood pressure telemonitoring versus the conventional treatment group. CI, confidence interval (reprinted with permission from reference [31•])

physicians (Misuriamo platform), and a smartphone mobile application (ESH CARE APP) were used, by randomizing 690 patients to either the ICT-based approach (POST) or the usual care, just based on repeated conventional visits by the physician in charge. In this RCT, patients randomized to the POST intervention transmitted their BP data to their doctor through the Internet. On the other side, data were collected on a web-based platform, Misuriamo, which, in addition to this feature, acted like an interactive clinical record, allowing demographic and specific clinical information to be stored for each patient, associated with cardiovascular risk quantification and real-time calculation of therapeutic targets according to the most recent guidelines. In the POST group, the ESH CARE APP, a validated smartphone/tablet application with educational and informative content endorsed by ESH, was made available to patients. BP and body weight data collected by this app and/or through a home personal computer–based system could be stored and transmitted to the Misuriamo platform accessed in a cloud through the personal computer of the physician in charge. The ESH CARE APP also allows a precise management of patient's drug treatment through phone alarm reminders. Finally, it represents a simple but comprehensive educational tool, as it includes a "question and answer" section, where most common questions about hypertension are managed, and offers a "general overview" of all practical issues related to hypertension. ESH CARE APP also improves health facility accessibility by providing an interactive list of ESH excellence centers throughout Europe, with the necessary contact information. This app, in its first release, was launched during the 2015 ESH annual meeting (Fig. 3).

Limitations and Future Perspectives

Important steps have been made in order to explore digital health potentialities in the primary and secondary prevention of CVD, in particular when considering hypertension management. Nevertheless, many gaps in knowledge still remain and need to be addressed.

First, a wider experimental use of digital health, and especially mobile health, is advisable in a primary care setting in order to truly understand its utility when routinely applied in a real-life setting and over a long-term period. There is need to test in daily practice the applicability, usefulness, and sustainability of ICT tools which could integrate traditional care strategies, favoring both patient empowerment and clinician performance.

Second, academic–industry partnerships are needed to match a scientifically validated and rigorous information content with a business-oriented design and dissemination strategy, which could meet the different needs of patients' various lifestyles and preferences, and work across multiple digital Health platforms.

Furthermore, it is advisable to limit exclusion criteria in interventional studies aimed at preventing CVD events. Studies are required to investigate whether the effect of digital health differs by age, race/ethnicity, socioeconomic background, education level, and living environment (rural vs urban).

Moreover, focusing on primary prevention, we need to identify the behavioral targets that are improved by digital health interventions and linked to blood pressure reduction, given the controversial evidence yet available on this issue.

Fig. 3 Screenshots of the ESH Care APP

Finally, it is crucial to create and develop strategies to maintain patients' and doctors' engagement over time. This is key to the persistence in compliance improvement and lifestyle habit modification that has been highlighted as being of pivotal importance in recent guidelines. In this context, digital health might indeed offer a significant contribution to improvement.

Conclusion

The data analyzed and summarized in this review support the possible usefulness of digital health strategies in the prevention and management of hypertension and related CVD risk factors, when compared to conventional care. Further research is however needed to identify the most effective digital health modalities and to better understand the determinants of their success in specific patient populations.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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