



Home blood pressure measurement self-reporting in real-life practices using the Hy-Result app: self-monitoring and digital pathway

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Background: Little real-life information is available on the clinical characteristics of information and communication technologies (ICTs) users, particularly in the context of hypertension and home blood pressure measurement (HBPM). This retrospective observational study describes HBPM practices obtained through the Hy-Result[®] system, a validated app designed to help patients perform HBPM and understand their results through an automatic interpretation of the readings using web interface.

Methods: We analyzed 19,176 HBPM reports (sequence of 1 to 7 days of measurements; 3 in the morning, 3 in the evening) collected in real life circumstances from two groups of users: primary care (Prim) and hypertension center (Hosp).

Results: Population: among the 19,176 reports, 63.2% declared receiving antihypertensive medication, having diabetes (15.2%), chronic kidney disease (9.7%) or history of stroke (7.6%). Treated users were older than normotensives [mean ± standard deviation (SD) age 64±12 vs. 58±14 years] with higher prevalence of comorbidities. Compliance with the HBPM schedule: the majority of reports (90.2%) totaled 15 systolic blood pressure (SBP) and diastolic blood pressure (DBP) readings or more, of which 96.1% were Hosp users and 89.3% Prim users, with a significant difference between both groups (P<0.001). The compliance rate for 7 days of measurement was higher in the Hosp group (57.6% vs. 30.5%; P<0.001). Blood pressure (BP) levels: in the 17,289 reports with a minimum of 15 readings, 42.7% had an average SBP and/or DBP above the recommended thresholds (below 135 and/or 85 mmHg), among whom, 36.8% were untreated subjects. Hosp users had better BP control than Prim (P<0.001). Users that are followed in the European Society of Hypertension (ESH) excellence center (Hosp) had better BP control than those in a Prim setting (P<0.001). HBPM oscillometric devices: in both groups, treated patients and untreated users, used the arm cuff devices more frequently than the wrist device.

Conclusions: Our real-life study shows that 90% of the HBPM reports include the required minimum number of BP readings to allow the calculation of a reliable average among whom 40% have uncontrolled BP levels. The self-management Hy-Result web app demonstrates significant potential for inclusion in the patient care process and reinforces the patient's engagement to independently monitor and self-reported their BP. When the mean BP is not within the recommended range, the users were automatically prompted by text messages to seek medical advice by the software. Further research should determine the extent to which users adhere to text messages advice.

Keywords: Home blood pressure measurement (HBPM); hypertension; blood pressure (BP); eHealth; self-reporting

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Introduction

There is growing evidence that the information and communication technologies (ICTs) and home blood pressure measurement (HBPM) can improve health care access, patient education, compliance to treatment and outcomes, particularly in chronic diseases such as arterial hypertension (1-3). However, little real-life information is available on the clinical characteristics of ICT users, particularly in the context of hypertension and HBPM. In this e-Health context, our group validated previously, a software system named Hy-Result[®], to help patients and professionals in the management of HBPM (4-6). The patients' reported data collected by the system give an original look on real life practices in the use of eHealth tools and HBPM. The aim of this study is to describe user's HBPM practices in real-life circumstances through data collected by the Hy-Result[®] system.

Methods

Software

Hy-Result is a validated system. A first study evaluated whether the algorithm classification of the blood pressure

(BP) status was in accordance with the physician's classification (blinded to the software's results) following a consultation (n=195 patients) and shows that classification by Hy-Result is similar to that of a specialist in current practice (4). A second, study assessed the experience of patients with the functionalities and medical content of Hy-Result, their feelings and expectations, and the impact of Hy-Result on the physician-patient relationship. It concluded that most of the users (n=512) described Hy-Result as an easy-to-use and useful tool (5). Additional study shows that the majority (88%) of pregnant women (n=107) performed HBPM and successfully used the Hy-Result software for self-interpretation of the BP readings (6).

Hy-Result is designed to help patients to: (I) perform HBPM according to a standardized protocol; (II) understand their results; and (III) share his/her BP readings with their doctor or nurse in a PDF format report (4-6). The data is generated through the Hy-Result web interface using a home conventional oscillometric monitor (with an upper-arm or a wrist cuff) and following an eHealth self-management protocol in accordance with the European Society of Hypertension (ESH) guidelines (2,7).

After measuring their BP according to the Hy-Result protocol (sitting position, three measurements 1 or 2 minutes apart, morning and evening for 3 to 7 consecutive days), the patient connects to "hy-result.com" enters their systolic BP (SBP) and diastolic BP (DBP) in the web interface and provides their medical profile (characteristics taken into account by the Hy-Result algorithm, *Table 1*). After clicking the "calculate" button, the software automatically generates a PDF analysis report using the Hy-Result[®] algorithm. This PDF report reconstructs the data in the form of graphs (*Figure 1*) and text messages written in user-friendly language (*Appendix 1*) and color-coded. *Table 2* summarizes the classification of color codes. When the mean BP is not within the recommended range, the users were automatically prompted by text messages to seek medical advice by the software. The data (medical profile + BP measurements) are recorded anonymously in a secure database.

Study design and data collection

This is a retrospective observational study conducted using

Highlight box

Key findings

- Hy-Result web app database [510,983 systolic blood pressure (BP) and diastolic BP readings collected in real life circumstances] shows that 90% of the home BP measurement (HBPM) reports include the required minimum number of BP readings to allow the calculation of a reliable BP average.
- From 17,289 HBPM sequences of more 15 consecutive BP readings, 40% have uncontrolled BP levels.

What is known and what is new?

- Digital tools improve self-management
- The Hy-Result web app reinforces the patient's engagement to independently monitor and self-reported their BP. The Hy-Result database may serve as a public health tool.

What is the implication, and what should change now?

- When the mean BP is not within the recommended range, the users are automatically prompted by automatic text messages to seek medical advice by the software. Further studies are needed to demonstrate the beneficence of this information in lowering BP.

Hy-Result® database between November 2021 and October 2022. We collected, in our secure database, 21,158 reports compiled in an Excel file format. Each report corresponds to a set of self-measurement sequences (1 to 7 consecutive days), recorded by one user.

For analysis, we included patients aged between 18 and 90 years. Because the usual practice of HBPM is accompanied by aberrant values due to malfunctions of BP monitoring and/or users input errors, we excluded 270 reports (1.4%) with aberrant values defined as follows:

DBP <40 or >140 mmHg; SBP <80 or >250 mmHg. (These thresholds are arbitrary but mainly based on the technical limitations of some devices. Above these ranges of readings, automatic analysis by the software is questionable without verification of monitor reliability, measurement procedure quality, and clinical information. Since such verification is impossible, we prefer to exclude such extreme values, which constitute a tiny minority of the data, to avoid any hazardous interpretations). The software cannot differentiate between an aberrant value which is due to a tensiometer’s technical problem or a manual input mistake (misreporting). We also excluded patients with a body mass index lower than 14 kg/m² or higher than >40 kg/m² because of the risk of error measurements due to unadapted cuff size. Overall, we analyzed 19,176 HBPM reports collected in real life circumstances from French users (see flow chart, Figure 2). The Hy-Result database totaled 510,983 SBP and DBP readings.

The characteristics and medical history are self-declared by users: age; gender; the use or not of antihypertensive treatment; history of diabetes, stroke, chronic kidney disease; the use of oral contraception; current pregnancy; current tobacco use; number of alcohol drinks per day (Table 1). A user is considered hypertensive if he declares taking an antihypertensive drug. Two groups of users are differentiated according to the source of recruitment, primary care (Prim), or hypertension center (Hosp) of an ESH excellence center:

(I) Prim users: this group is composed of health

Table 1 Medical profile (self-reported data)

Question	Response
Gender	Male/female
Age (years)	18 to 90
Height (cm)	60 to 210
Weight (kg)	30 to 140
Undertaking antihypertensive treatment	Yes/no
Current smoker	Yes/no
Number of alcohol drinks per day (glass)	0 to 5 or more
Past medical history of stroke	Yes/no/I don't know
Diabetes	Yes/no/I don't know
Chronic kidney disease	Yes/no/I don't know
Use of contraceptive pills	Yes/no
Pregnancy	Yes/no

My measures

Overall systolic average **133**, diastolic average **79**
 You have recorded **42** systolic pressure measures (SYS)
 You have recorded **42** diastolic pressure measures (DIA)
Measures not taken into account: 0 (PAS >100 & PAS-PAD ≤10), PAS <60 or >300, PAD <40 or >140, PAD > PAS

Systolic pressure



Morning average: **133 mmHg**
 Evening average: **132 mmHg**

Diastolic pressure



Morning average: **78 mmHg**
 Evening average: **79 mmHg**

My week of measures

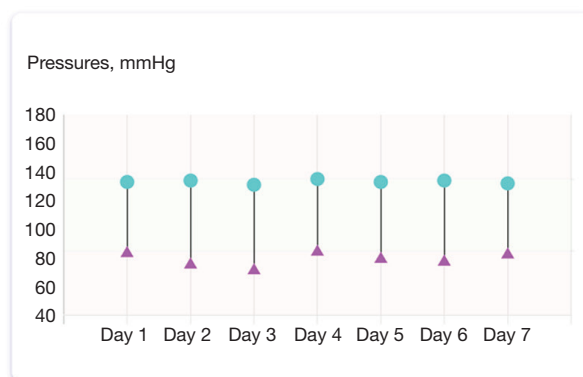


Figure 1 Example of a Hy-Result report (screenshot).

Table 2 Hy-Result® color code classification

Hy-Result® color code	Classification
Gray	Without treatment: SBP ≤100 mmHg Treated hypertension: SBP ≤115 mmHg or DBP ≤65 mmHg
Green	SBP 101–135 mmHg and DBP 66–85 mmHg
Orange	SBP 136–150 mmHg and/or DBP 86–100 mmHg
Red	SBP ≥151 mmHg and/or DBP ≥101 mmHg

SBP, systolic blood pressure; DBP, diastolic blood pressure.

consumers who find the website by themselves on the Internet (hy-result.com) or patients following the recommendation of their physician (e.g., general practitioner or cardiologist). For this group, we are not aware of the existence of any self-measurement education input. However, we do know, that they followed the instructions given by the system because otherwise they could not complete the web interface and fill in their BP measurements.

(II) Hosp users: this group corresponds to those who

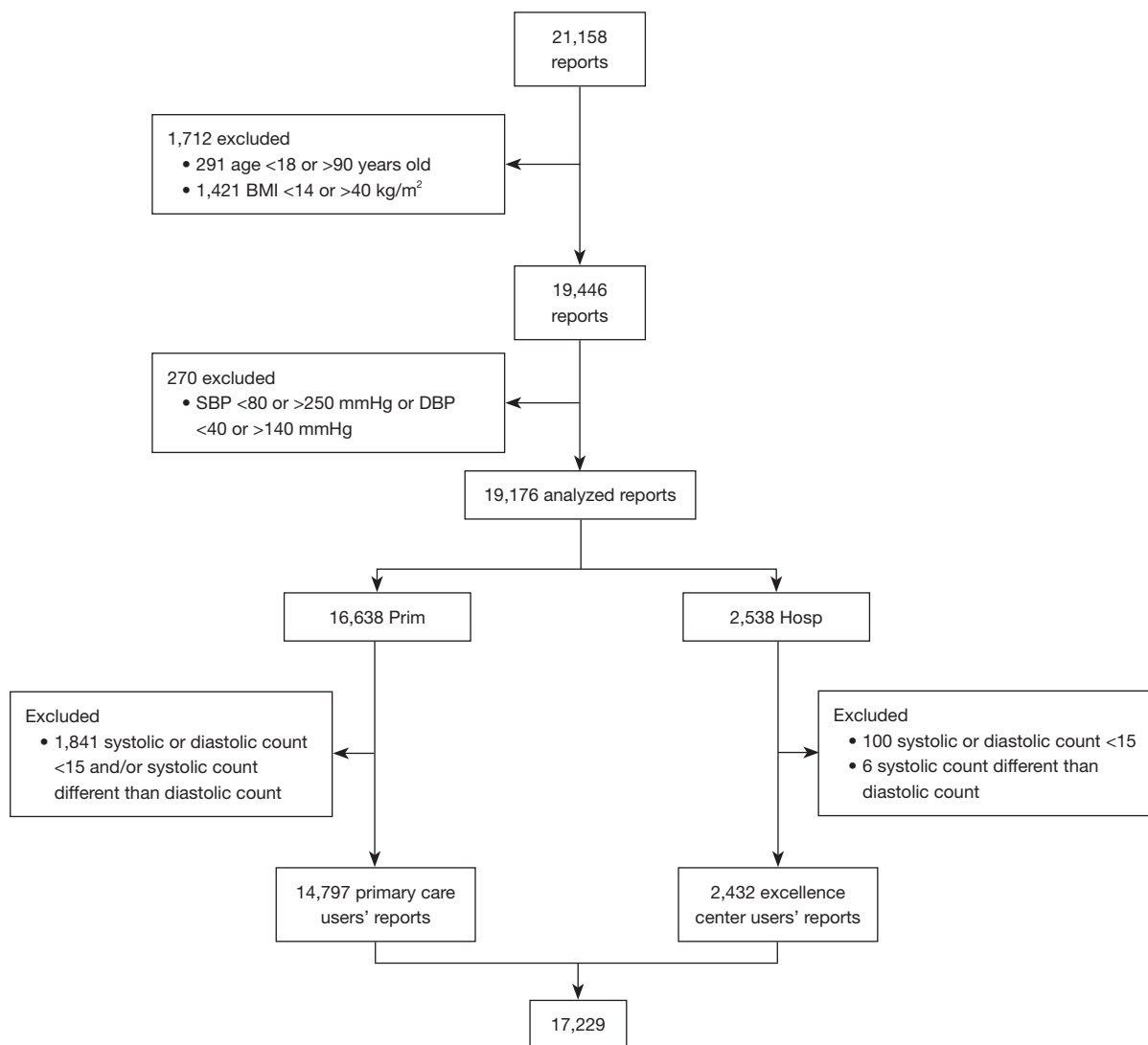


Figure 2 Flow chart. BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; Prim, primary care; Hosp, hypertension center.

use the web application as per the recommendation of a physician who works in an ESH excellence center (Georges Pompidou European Hospital, Paris, France). In this center, patients are instructed on how to correctly measure their home BP by a nurse and they receive a 4-page leaflet that explains how to use the Hy-Result[®] web interface which is designed for self-management use. (The leaflet is also available online in PDF format). To use the software, these patients did not receive any subsequent help from a health professional.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics Version 26.0 and conducted between January and April 2023. Categorical variables were summarized as frequency and percentage. Continuous variables were presented as mean, standard deviation (SD), median, minimum, and maximum. Shapiro test was used to test the normality of continuous variables. This test is used to determine if two categorical variables are independent or if they are related to one another. In this study, we used the *t*-test to assess the significance of differences in mean values between two independent groups, while the Pearson correlation coefficient was employed to evaluate the strength and direction of relationships between two continuous variables. An aberrant value is defined by having either a SBP <80 or >250 mmHg or a DBP <40 or >140 mmHg. A manual input error is defined if any of the following occurs: (I) error count: the SBP count is different than the DBP.

Both international hypertension and HBPM guidelines recommend performing a minimum number of BP measurements over a few days to obtain an accurate and a reproducible estimate of the average BP values. A minimum of 12 SBP and 12 DBP readings, taken on 3 (consecutive) days, are needed for the reproducibility of HBPM to be superior to that of conventional measurements (8,9). In our study, BP levels are analyzed in the subgroup of reports having a minimum of 15 SBP and 15 DBP in accordance with the French guidelines recommending three measurements morning and evening.

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Before using the app, users agreed to the use of their data for

research purposes (app' user agreement). According to French law, IRB approval was waived for the study of a completely anonymous database. Data collection, storage and processing complied with European General Data Protection Regulations (GDPR).

Results

A total of 19,176 reports are analyzed (*Figure 2*). The database provides medical information on the users (age, gender, cardiovascular risk factors, and cardiovascular events), BP levels, compliance—or not—with the measurement protocol and the types of sphygmomanometers used (arm or wrist). For BP level reliable analysis, we then excluded patients with systolic or diastolic count <15 and users with a systolic count different from the diastolic count. We ended up with 17,229 reports (14,797 reports of Prim users and 2,432 reports for patients followed-up in an ESH excellence center).

Population

Of the 19,176 reports, 63.2% declare receiving antihypertensive medication (n=12,117). In this group, the mean \pm SD age is 64 \pm 12 years of whom 60.7% are male (n=7,350). Diabetes, chronic kidney disease, and stroke are declared in 15.2%, 9.7%, and 7.6%, respectively (n=1,843, 1,171, and 918, respectively) (*Table 3*). Untreated group is younger with a mean \pm SD age of 58 \pm 14 years and with a lower prevalence of comorbidities (*Table 3*). When comparing reports from treated patients in the Prim *vs.* Hosp group, we find that the first group is older with a mean \pm SD age of 65 \pm 11 *vs.* 58 \pm 14 years. Fewer have chronic kidney disease and stroke [8.2% (n=829) and 7.2% (n=723) *vs.* 16.6% (n=342) and 9.5% (n=195), respectively]. The prevalence of diabetes is slightly higher in the prim group [15.5% (n=1,556) *vs.* 13.9%] (*Table 4*).

Numbers of readings and compliance with the HBPM schedule

Web app instructions are: “Measure your BP for 3 to 7 days in a row and fill the table”. *Table 5* shows the total numbers of readings per report. The large majority of reports (90.2%, n=17,289) totaled 15 BP readings or more, among which 96.1% were Hosp users (n=2,438) and 89.3% were Prim users (n=14,851) with a significant difference between the groups (P<0.001). *Figure 3* compares

Table 3 Characteristics of the study population (n=19,176)

Characteristics	Treated group	Untreated group	P value
Total	12,117 (63.2)	7,059 (36.8)	NA
Age (years)	64±12	58±14	<0.001
Gender			<0.001
Male	7,350 (60.7)	3,801 (53.8)	
Female	4,767 (39.3)	3,258 (46.2)	
BMI (kg/m ²)	27.2±4.3	26.5±4.2	0.02
Current smoking	774 (6.4)	688 (9.7)	<0.001
Alcohol			0.12
0 glass/day	7,451 (61.5)	4,458 (63.2)	
>5 glasses/day	43 (0.4)	23 (0.3)	
Diabetes	1,843 (15.2)	561 (7.9)	<0.001
Chronic kidney disease	1,171 (9.7)	240 (3.4)	<0.001
Stroke	918 (7.6)	347 (4.9)	<0.001

Data are presented as n (%) or mean ± SD. NA, not available; BMI, body mass index; SD, standard deviation.

Table 4 Comparison of the cardiovascular risk factors between Hosp and Prim groups (n=19,176)

Factors	Hosp (ESH excellence center; n=2,538, 13.2%)			Prim (n=16,638, 86.8%)		
	Treated	Untreated	P value	Treated	Untreated	P value
Total	2,058 (81.1)	480 (18.9)	NA	10,059 (60.5)	6,579 (39.5)	NA
Age (years)	58±14	55±16	<0.001	65±11	59±14	<0.001
Gender			<0.001			<0.001
Male	1,265 (61.5)	247 (51.5)		6,085 (60.5)	3,554 (54.0)	
Female	793 (38.5)	233 (48.5)		3,974 (39.5)	3,025 (46.0)	
BMI (kg/m ²)	26.9±4.4	25.5±4.2	<0.001	27.2±4.3	26.6±4.2	0.09
Tobacco	155 (7.5)	49 (10.2)	0.05	619 (6.2)	639 (9.7)	<0.001
Alcohol			0.008			0.004
0 glass/day	1,426 (69.3)	328 (68.3)		6,025 (59.9)	4,130 (62.8)	
>5 glass/day	6 (0.3)	0 (0.0)		33 (0.3)	15 (0.2)	
Diabetes	287 (13.9)	33 (6.9)	<0.001	1,556 (15.5)	528 (8.0)	<0.001
Chronic kidney disease	342 (16.6)	68 (14.2)	0.18	829 (8.2)	172 (2.6)	<0.001
Stroke	195 (9.5)	34 (7.1)	0.10	723 (7.2)	313 (4.8)	<0.001

Data are presented as n (%) or mean ± SD. Hosp, hypertension center; Prim, primary care; ESH, European Society of Hypertension; NA, not available; BMI, body mass index; SD, standard deviation.

Table 5 Number of BP (SBP/DBP) readings per report according to the recruitment groups

Subgroups	BP readings per report		P value
	≤14	≥15	
Hosp (n=2,538)	100 (3.9)	2,438 (96.1)	<0.001
Prim (n=16,638)	1,787 (10.7)	14,851 (89.3)	

Data are presented as n (%). BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; Hosp, hypertension center; Prim, primary care.

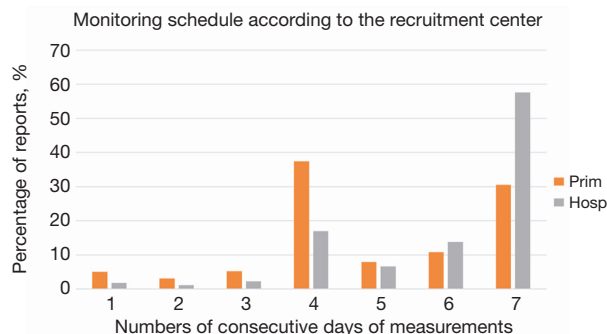


Figure 3 Comparison of the compliance with the HBPM schedule regarding the numbers of consecutive days of measurements between the centers of recruitment. Prim group vs. Hosp group. Prim, primary care; Hosp, hypertension center; HBPM, home blood pressure measurement.

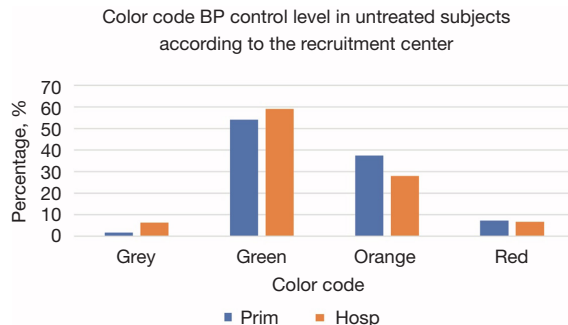


Figure 5 Color code BP control level in untreated subjects according to the recruitment center. Prim group vs. Hosp group. BP, blood pressure; Prim, primary care; Hosp, hypertension center.

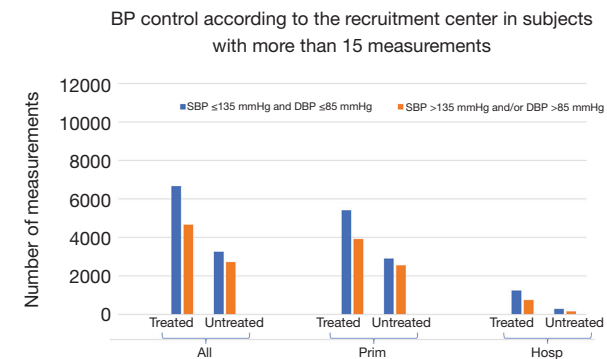


Figure 4 BP control according to the recruitment center in reports with more than 15 measurements (n=17,229). Prim group vs. Hosp group, vs. all group (Prim + Hosp). SBP, systolic blood pressure; DBP, diastolic blood pressure; Prim, primary care; Hosp, hypertension center; BP, blood pressure.

compliance with the HBPM schedule regarding the number of consecutive days of measurements between the centers of recruitment: 5% of Prim users (n=830) vs. 1.8% of Hosp

users (n=46) did less than six measurements. We collected 17,229 reports with at least 15 measurements. In this subgroup, the compliance rate for 7 measurements days was higher in the Hosp group with 57.6% (n=1,463) vs. 30.5% (n=5,081).

BP levels

Figure 4 presents the achievement of BP control (threshold of 135/85 mmHg, as defined by ESH guidelines), according to patients' groups (Prim or Hosp) among treated and untreated users. To ensure reliability in our analysis, we focused on examining a subgroup consisting of 17,289 reports that included at least 15 BP measurements. In this subgroup, 42.7% (n=7,378) had an average SBP and/or DBP above the recommended thresholds (below 135 and/or 85 mmHg), among whom, 36.8% were untreated subjects (n=2,716). Users that are followed in the ESH excellence Hosp had better BP control than those in a Prim setting (P<0.001).

To facilitate patient understanding, the Hy-Result algorithm classifies SBP and/or DBP averages into four color codes (gray corresponds to low pressures, normal to green, and orange or red to pressures above thresholds).

Figure 5 and Figure S1 show the repartition of color code according to the BP levels. Patients' cardiovascular risk factors of normal or low BP (gray color code) are summarized in Table 4. In this group, 93.5% are treated patients (n=1,606).

HBPM oscillometric devices

Upper arm cuff devices were used in 80.7% of Prim users (n=13,628) and in 93.1% of Hosp users (n=2,318), with a significant difference ($P<0.001$). In both groups, treated patients used the recommended arm cuff more frequently than the untreated users (Table S1).

Discussion

Strengths and limitations

The analyzed data relates to 19,176 reports totaling 510,983 SBP and DBP readings. It offers a large-scale quantitative observation on HBPM practices in a real-life setting. This retrospective examination of the Hy-Result database provides a unique insight into the behavior of two groups as they self-measure their BP at home using their personal devices and engage with ICT through a web interface, all without the supervision of healthcare professionals. The methodology employed here does not introduce any clinical trial bias. Clinical trials based on HBPM typically differ from real-life scenarios due to differences in inclusion criteria, the requirement for consent, and the presence of instructions, which can vary from providing information or education to occasionally supplying study-specific monitors. Therefore, this retrospective analysis without intervention is a good way of observing real-life behaviors. We acknowledge limitations stem from the technical characteristics of the software: because it is anonymous, the data does not distinguish between the number of reports and the number of users; each user does not have a single ID to log in; therefore, if a user enters multiple sets of HBPM, we will collect multiple reports in our database that cannot be identified as belonging to the same user. In other words, the 19,446 reports do not correspond exactly to 19,446 users. The data do not provide information how patients interact with the program, particularly BP submissions at repeated intervals over time. This information will be available in a new version of the software.

Population

The distribution of the age, gender ratio and BMI of the Hy-Result® system users is consistent with the epidemiological knowledge observed in France where the prevalence of hypertension is higher in men than in women (34% vs. 28%) and increases with age (10). The same is true for the population attending an ESH excellence center, which is younger than that of a Prim setting. It is consistent to note that the patients under antihypertensive medication are older and suffer from a higher rate of comorbidities (diabetes, chronic kidney disease, and/or stroke) than those untreated. It is important to note that patients who perform HBPM and use a digital tool are not representative of the general population. In France, only 20.9% of the Esteban study adult population possess a HBPM device (10).

BP levels

On the one hand, our study finds that approximately half (43%) of the reports of treated patients do not have BP levels under control; this is consistent with other studies that show that the control rate among the hypertensive population is estimated between 40% to 50% in Europe (11). In France, a national study shows that among those treated, 45% had uncontrolled BP (55% in men and 33.5% in women) (12,13). On the other hand, a significant proportion (41%) of the reports are generated by untreated subjects. This is original data for which we lack comparison in the literature.

Uncontrolled BP levels

In our population, 45.4% of untreated patients have uncontrolled BP levels. However, our data do not allow us to know whether self-measurement is carried out as part of a self-screening process or at the request of a health professional to diagnose hypertension. In the Hosp group, the proportion of hypertension without treatment is 35.9%. These are patients in whom the healthcare professional was looking for white coat hypertension (WC-HTN) or patients whose treatment had been temporarily stopped to allow exploration (such as hormonal dosage of renin and aldosterone levels for example). Assuming that people consulting a tertiary center have had previously observed high BP at some time in the past, the percentage of 35.1% could correspond to that of the white coat effect. Although

our hypothesis is fragile, this rate is plausible since data from the literature suggest that 20% to 40% of patients initially diagnosed as hypertension may have WC-HTN even if it is impossible to posit a precise number due to variation in different populations (as Prim *vs.* Hosp center) (14). In a Prim setting, a study found a prevalence of 39% of WC-HTN (15).

Low BP level

The Hy-Result algorithm cut-off for the gray color code is 115/65 mmHg which corresponds to the lower BP target as per the ESH 2023 guidelines (7). These guidelines indicate that an office SBP <120 mmHg and DBP <70 mmHg cannot be recommended in several situations such as diabetes mellitus or chronic kidney disease). In our study, 8.3% of the treated population have a low BP level. Are these patients (Figure S1) over treated? To answer we should consider the patients' tolerance and orthostatic hypotension. To answer this question, we need to consider patient tolerance and orthostatic hypotension. Unfortunately, these data are not available with a sitting measurement. In these cases (gray zone classification), text messages invite users to check their BP with their doctor.

HBPM oscillometric devices

Hy-Result' users web app declare that they mostly use brachial rather than radial cuff devices (80% in the Prim group and 93% in the Hosp group). This is probably because patients followed up in an ESH excellence center are trained in the proper protocol for HBPM. These proportions are higher than those found in the FLAHS survey, which estimates that half of treated hypertensive patients are equipped with brachial cuff-type BP monitors, whereas in subjects without treated hypertension, wrist monitors are used in the majority of cases (16). In France, the distribution of arm or wrist BP monitors sold in pharmacies was identical (17). The instructions provided through the Hy-Result app advise patients against using wrist devices. This is a necessary information since BP monitors can be bought without the guidance of a health provider (i.e., supermarkets or Internet).

HBPM schedule

Having a reliable HBPM is crucial because correct BP measurement is a prerequisite for appropriate medical decision-making (diagnosis and/or drug titration).

Healthcare providers are concerned about the low adherence to self-measured BP monitoring schedules by patients (18,19). The monitoring schedule and protocol might be poorly explained by health professionals. According to a French study, only 17% of general practitioners teach their patients how to perform standardized HBPM (20). The Hy-Result app is designed to help patients to respect the recommended schedule. Overall, the vast majority (90%; n=17,289) of Hy-Result reports include the minimum number of measurement days required by the ESH guidelines (2,7). This rate reaches 96% for Hosp group which has received specific training from a nurse.

The value of 90% derives from a select, motivated and willing subset of individuals. Website traffic statistics show that of all visitors to the home page, roughly two-thirds enter their BP readings to calculate their average BP (first step). Half of them proceed to the second and final step (by completing their medical profile, entering their BP results, and clicking the "calculate" button). In a previous pilot study, we observed that 54% (n=304) of the new patients who booked via the Internet an appointment at our Hosp were able to prepare for their visit by going through a digital pathway and following the application's instructions for use (21).

HBPM and provider-perceived barriers

Healthcare providers highlight that the increased use of HBPM monitoring, along with education and communication, will affect their daily practice (staff workload, telephone calls, email messages, etc.). They are also concerned about the extra time needed for interpreting self-measured BP readings (19). For these reasons, the Hy-Result app was designed for a self-management approach, as distinct from a telemonitoring approach (22).

Electronic oscillometric devices require little to no training and are generally not affected by an observer bias; if used correctly (23). The app automatically calculates SBP and DBP averages and classifies them into four color zones in accordance with the ESH guidelines. Manual input of readings may be sometimes wrong (misreporting), but on average, possible errors in notation had almost no influence on the mean BP, as shown in a study with a memory-equipped electronic device (24). Database shows that 90% of the HBPM reports include the required minimum number of BP measurements to allow the calculation of a reliable average. According to a pilot study in our tertiary center, approximately half of the patients (54%)

were able to successfully negotiate the Digital Path with either Hy-Quest and/or Hy-Result completed (5 days self-measurement minimum) (21).

Conclusions

In conclusion, our real-life study shows that 90% of the HBPM reports include the required minimum number of BP readings to allow the calculation of a reliable average among whom 40% have uncontrolled BP levels. The self-management Hy-Result web app demonstrates significant potential for inclusion in the patient care process and reinforces the patient's engagement to independently monitor and self-reported their BP.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Before using the app, users agreed to the use of their data for research purposes (app' user agreement). According to French law, IRB approval was waived for the study of a completely anonymous database. Data collection, storage and processing complied with European General Data Protection Regulations (GDPR).

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Appendix 1*Automatic text message generated by Hy-Result software: example 1*

You have indicated that you are taking antihypertensive medications and are under the age of 50 years. Your BP moderately exceeds the desired values (target BP). Given your age, start by reducing or avoiding excess weight (you should have a body mass index below 25 kg/m²), do not smoke and do not consume alcoholic beverages in excess. In these BP values at your age, the benefit of lowering BP with antihypertensive drugs has not been well demonstrated. On the other hand, regular physical exercise and a diet avoiding high salt intake, (in particular that provided by pre-cooked dishes or added to the cooking of dishes or on the plate), are two good habits to adopt. They are very beneficial. If you have cholesterol or diabetes or a family history of cardiovascular disease under the age of 65 years in your parents or siblings, check with your doctor. Check your BP yourself regularly, for example in 4 to 6 months.

- ❖ You have reported taking oral contraception. Be aware that some pills containing estrogens are not recommended in case of hypertension. Read the instructions for your pill to check it and talk to your doctor.
- ❖ Overall, your BP is in orange with high values. Check that you are taking your medication regularly. Your treatment may need to be adjusted. Ask your doctor if it is appropriate to reinforce your treatment (increased doses or addition of a drug). Tension in orange justifies medical advice.

Automatic text message generated by Hy-Result software: example 2

- ❖ You have reported taking antihypertensive therapy. Your BP exceeds desirable values. According to your indications, you declared that you had one (or more) illnesses that justify your BP being closely monitored. You should see your doctor to discuss the benefits of adjusting your treatment.
- ❖ You reported having diabetes. Experts from the European Society of High Blood Pressure recommend, in case of diabetes, to reach under treatment a BP below 140 mmHg for systolic and 85 mmHg for diastolic when it is measured in a medical environment, probably below an average of 135/80 mmHg in self-measurement. They also recommend that the systolic pressure under treatment should not drop below 120 mmHg in the medical office, or 115 mmHg in self-measurement. In other words, the tension should not be neither too high nor too low.
- ❖ You have declared that you are a smoker. As you know, it is recommended to stop smoking, whether or not you have high BP. This is even more important in the case of diabetes and hypertension. Cutting out smoking helps prevent many cancers, including cancers of the lungs, throat, and bladder.
- ❖ Overall, your BP is in orange with high values. Check that you are taking your medication regularly. Your treatment may need to be adjusted. Ask your doctor if it is appropriate to reinforce your treatment (increased doses or addition of a drug). Tension in orange justifies medical advice.

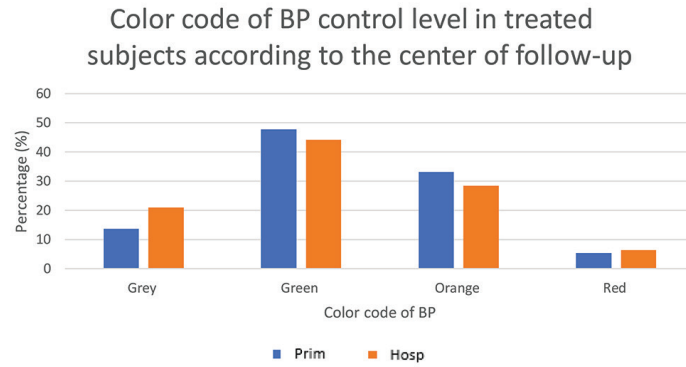


Figure S1 Color code BP control level in treated subjects according to the recruitment center. Prim group *vs.* Hosp group. BP, blood pressure; Prim, primary care; Hosp, hypertension center.

Table S1 BP oscillometric devices

Groups	Upper arm cuff	Wrist cuff	P value
Hosp			<0.001
All (n=2,558)	2,381 (93.1)	177 (6.9)	
Treated (n=2,068)	1,947 (94.1)	121 (5.9)	
Untreated (n=490)	434 (88.6)	56 (11.4)	
Prim			<0.001
All (n=16,888)	13,628 (80.7)	3,260 (19.3)	
Treated (n=10,136)	8,336 (82.2)	1,800 (17.8)	
Untreated (n=6,752)	5,292 (78.4)	1,460 (21.6)	

Data are presented as n (%). BP, blood pressure; Hosp, hypertension center; Prim, primary care.