# Using Physical Activity Monitor to Check a Patient´s Rest before Blood Pressure Measurement During Home Blood Pressure Telemonitoring

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**Abstract**

Home blood pressure telemonitoring (HBPTM) with automatic data capturing and its transfer enables us to effectively monitor a patient´s blood pressure measurements at home environment, to eliminate transcription errors and, in combination with physical activity monitoring, to check a patient´s taking the recommended time 5 min to rest before BP measurements.

The data of 35 patients with essential hypertension using Diani telemonitoring system were used to evaluate the suitability of using activity trackers to monitor patients´ step counts before and during the BP measurements. Two datasets (scheduled measurements and daytime profile ones) were processed separately and compared. The majority (83.6%) of data were indicating zero steps before BP measurements with no significant difference either between scheduled measurements and daytime profile ones or between men and women. Standards for the limit of acceptable step counts in a defined time window before each BP measurement could be set when larger datasets are available.

**Keywords**

Blood pressure, home blood pressure telemonitoring, home blood pressure monitoring, activity tracker, telemedicine, self-monitoring.

## 1 INTRODUCTION

Hypertension is one of the most common chronic diseases requiring a long-term care. The overall prevalence of hypertension in adults is around 30-45%, increasing progressively with advancing age. [1].

Self-monitoring of blood pressure by patients at home (home blood pressure monitoring – HBPM) is being spread in many countries and is well accepted by patients [2].

HBPM should be performed by trained subjects/patients, always under the supervision of their doctor [2]. There is also evidence that patient´s self-monitoring may have a beneficial effect on medication adherence and BP control [3,4].

Home BP is described in ESC/ESH Guidelines as follows: *"Home BP is the average of all BP readings performed with a semiautomatic, validated BP monitor, for at least 3 days and preferably for 6–7 consecutive days before each clinic visit, with readings in the morning and the evening, taken in a quiet room after 5 min of rest, with the patient seated with their back and arm supported. Two measurements should be taken at each measurement session, performed 1–2 min apart."* [5]

However, BP values reported by the patient may not always be reliable due to transcription errors. Some patients even select the more optimistic lower BP values from multiple measurements. Mistakes can altogether reach up to 30 % of all reported BP values. [8]

To eliminate these errors, mobile and web applications may be used to store and review BP data in a digital diary and transmit them automatically from connected devices [5-8].

Another source of invalid measurements can be when optimal time of rest before BP measurement is not respected. [9]

Moreover, thanks to the motion sensors we are able to track patients´ physical activity throughout a day, and also, just before and during the measurement. Such a tool can reduce the difficulty to check whether the patient takes a rest sitting relaxed before BP measurements as recommended. With this information we may better assess the reliability of a given BP value measured at home.

To our knowledge, no study in which the patient´s movement would be tracked during the blood pressure measurement have been done yet. Therefore, there are no existing standards that would evaluate reliability of

such a tracking method and define the limit of steps the effect of which on blood pressure can be considered as negligible.

In this study, we aim to demonstrate the feasibility of using activity trackers as a part of our HBPTM system to check and monitor patients´ 5 min rest before BP measurements.

## 2 METHODS

### 2.1 Home blood pressure telemonitoring

Diani telemonitoring system enables us to track blood pressure measured in home environment. There are two ways of data transfer: a) using a miniPC or Raspberry Pi connected to a FORA P30+ BP measuring device (monitor) and activity tracker Xiaomi MiBand 2, both supporting Bluetooth communication, or b) using a smartphone connected to the FORA P30+ BP monitor and activity tracker Xiaomi MiBand 2. These two different measuring sets enable the patients with different technical skills and their home environment facilities to use the system. The data transfer is fully automatic, without any patient´s interaction.

The data visualization and online sharing with clinicians is provided via a web application.

The web application visualizes parameters recorded by connected devices, i.e. systolic and diastolic blood pressure, heart rate from both the BP monitor and the activity tracker, and also arrhythmia occurrence, if detected by the BP monitor, and the intensity of physical activity represented with number of steps per time and recorded via a connected wristband activity tracker.

To ensure compliance with the recommendations of inactivity before and during the BP measurement, the patient´s movement is tracked by the activity tracker and evaluated in a 5-minute window prior to the measurement performance.

Any steps taken by a patient before or during BP measurements can be controlled through data displayed in a table that summarizes 1) results from the BP monitoring,

2) the intensity of movement as an average number from the 5-minute interval before the first BP measurement was made, 3) the number of steps 5 minutes before the measurement, and 4) the total number of minutes from the past 15-minute interval before the measurement in which no steps were made.

### 2.2 Recruitment of study participants

Adults pharmacologically treated with essential hypertension, who have sufficient abilities to self-measure blood pressure at home (i.e. have no physical obstacle to operate the monitor, understand the measuring process and are able to perform the measurement based on the obtained instructions) are included in the study. Patients were recruited by their preventive cardiologists and general practitioners

according to the mentioned criteria. Acceptance rate was by 80%. Exclusion criteria are pregnancy, diagnosis of atrial fibrillation, or inability to handle the operation of any device included in the device set.

### 2.3 Study sample

Thirty-five patients (24 men and 11 women) with essential hypertension, with an average age of 59±13 years and average weight 91.6±19.1 kg. The weight was measured in the study office just before starting the study. The patients were using HBPTM system in which activity tracking was included, were recruited for the study analysis.

### 2.4 Collected data

The data collected via connected devices include systolic and diastolic blood pressure values, heart rate, and number of steps in 1-minute intervals.

### 2.5 Instructions for patients

Each patient performs a cycle of BP measurements at the beginning of each month of the period of three months. For seven consecutive days the patient measures his BP twice a day - in the morning and in the evening, 3 measurements per occasion, 1–2 min apart (this is a scheduled week cycle). Sometimes, substantial differences were found between the two BP values taken at one HBPM session in the hypertension clinic. Therefore the number of measurements was increased to 3 measurements at each session. This modification of HBPM Guidelines was agreed by G.S. Stergiou, one of the authors of HBPM Guidelines [2].

During the first week of the study, the patient can select one day of that week to perform a daytime profile. It means the patient is required to measure BP every hour from the morning till the evening, starting immediately before the first morning medication intake to demonstrate possible hypotension during the peak effect of drugs (it had been additionally introduced for the hypertension clinic earlier). In remaining weeks, the patient can select one day in each week to check his/her BP either in the morning or in the evening.

The patients are also instructed to wear the activity tracker during the days in which BP is measured for the whole period of the 3 months. The instructions include requirement to place the wristband on the wrist of the arm which was not used for the BP measurement. Patients were informed that their rest before BP measurement would be checked via connected activity tracker.

### 2.6 Data analysis

From all the data of 35 patients we have selected those containing information about step counts and at least one nonzero heart rate record 15 minutes before or during the measurement. With this condition we can ensure the patient was wearing the activity tracker on his/her wrist.

Two datasets are processed separately and compared,

i.e. *daytime profile measurements* and *scheduled measurements* containing week cycle measurements and selected days with one occasional measurement in other weeks.

We have used the Wilcoxon signed rank test to test the null hypothesis of equal medians of relative frequency (%) of 0 step counts before the measurements in scheduled regimen vs. daytime profile days, and Wilcoxon rank sum test to test the null hypothesis of equal medians of men and women in each of these two regimens.

## 3 RESULTS

The data of 34 patients (24 men and 10 women) of the 35 patients we analysed contain scheduled measurements and the data of 27 of these 35 patients (18 men and 9 women) contain daytime profile data.

From all the measurements used for the analysis, 83.6% of the measurements (5768 records, the average number of records per patient is 193±116) signalized no steps during the 5-minute period before the measurement. The percentage of correct measurements in individual patients varied from 43.3% to 100% in case of scheduled measurements and from 23.1% to 100% in case of daytime profile measurements. The results are summarized in Table 1.

Figure 1 shows the frequency of measurements in each category of number of steps that appeared 5 minutes before the BP measurement.

There is no significant difference either between the scheduled measurements and daytime profile measurements ($p=0.7423$, see Figure 2) or between men and women in scheduled measurements ($p=0.6134$, see Figure 3) and in daytime profile measurements ($p=0.9793$, see Figure 4).

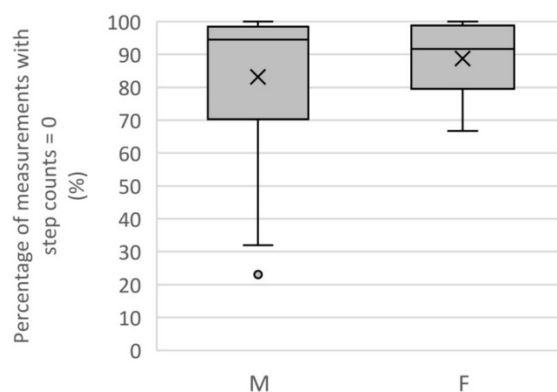| | All data | Daytime profile | Scheduled measurements |
|---|---|---|---|
| **Number of patients included** | 35 | 27 | 34 |
| **Total number of records** | 6899 | 977 | 5922 |
| **Number of records with step counts = 0** | 5768 | 852 | 4916 |
| **% of records with step counts = 0** | 83.6 | 87.2 | 83.0 |

**Table 1** An overview of the number of records in each measurement category and the percentage of correct measurements.
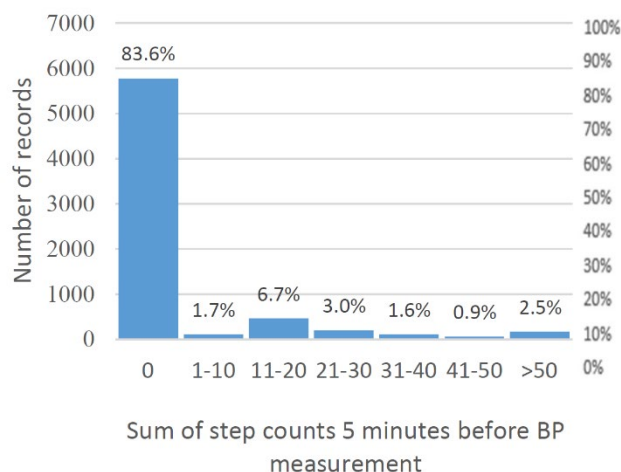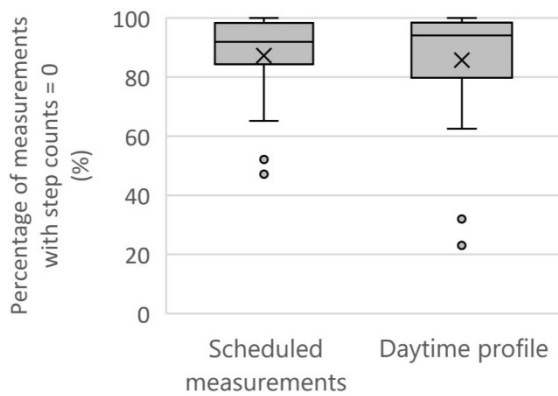


**Figure 1** Frequency of BP records in each category of number of steps that appeared 5 minutes prior to each BP measurement.
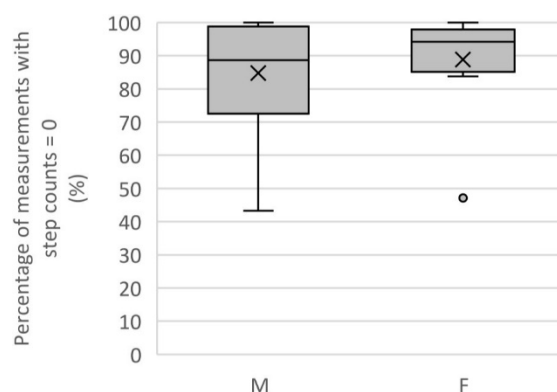


**Figure 2** Comparison of scheduled measurements with step counts = 0 for group of men (M, n=24) vs. group of women (F, n=10).



**Figure 3** Comparison of measurements from daytime profiles with step counts = 0 for group of men (M, n=18) vs. group of women (F, n=9).

**Figure 4** Comparison of patients´ scheduled measurements with step counts = 0 vs daytime profile measurements of these patients (n=26 for each group). Included are patients whose data contain both daytime profile and scheduled measurements.

## 4 DISCUSSION

BP telemonitoring together with physical activity monitoring could improve the reliability of HBPM, which is important in the time of recommended wider use of out- of-office BP measurement, especially HBPM. However, so far there have been no standards saying what the limits for the number of steps before the measurement for given time window are, and which limit should be considered as accepted for the relevance of measured value and which should not. Based on the results from our datasets visualized in Figure 1, we suggest to keep the limit for accepted measurement of 0 step counts in 5-minute window before each BP measurement, as a clear evidence of keeping the condition given by the current 2018 ESC/ESH Guidelines [5]. Due to the fact we have used each separated blood pressure measurement record, most of the measurements containing any step records higher than zero that comes from the first of the three separated measurements of each measuring session.

To ensure we process only those segments in which the patients were wearing the activity tracker on their wrist, we had to exclude all the data in which no measurement of heart rate 15 minutes before the measurement occurred, even though some step counts could be present at that time.

To ensure the heart rate is being measured correctly, it is also required to wear the wristband tight on one´s wrist.

Thus, proper education of each patient with respect to the wearing of the wristband should be included prior to the implementation of this method of control.

There was no significant difference either between types of measurements or between men and women, despite our expectation of at least gender differences.

Data from more patients need to be analysed to increase study power.

## 5 CONCLUSION

In this study we have presented the possibility of using a physical activity tracker in patients on HBPTM system to assess compliance with the resting regimen before BP measurement.

With proper instructions patients are able to keep rest before measurements. From the results we can conclude there was majority (83.6%) of data indicating zero steps before BP measurements with no significant difference either between scheduled measurements and daytime profiles or between men and women. Standards for the limit of acceptable step counts in a defined time window before each BP measurement could be set when larger datasets are available.

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## 7  ACKNOWLEDGEMENT