‘Home hypertension’: exploring the inverse white coat response

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SUMMARY

Background. The classical ‘white coat response’ to blood pressure measurement has been studied thoroughly. However, little is known about patients showing a reverse pattern, i.e. who have lower blood pressure readings at the clinic than outside healthcare facilities.

Aim. To estimate the proportion of patients whose blood pressure levels as determined by self-measurements at home are higher than those taken at the clinic and to explore possible associations with demographic, clinical, and psychological variables.

Method. Patients consecutively attending (n = 214) an academic family medicine department in Toronto, Canada, were eligible. Subjects aged below 16 years and those on psychotropic or blood pressure-lowering agents were excluded. The clinic–home blood pressure difference (CHBPD) was calculated for each participating subject by subtracting home blood pressure from clinic blood pressure. Those who had negative values were compared with the rest of the sample.

Results. A considerable proportion of patients had lower blood pressure at the clinic than at home (systolic, 34.6%; diastolic, 23.8%). These subjects did not differ from the rest of the sample with regard to age, sex, levels of education attained, immigration status, body mass index, experience of current symptoms, blood pressure levels, or psychological distress. However, in patients with a ‘negative CHBPD’, i.e. lower blood pressure at the clinic than at home, readings taken by an automatic, self-inflating device when still at the clinic were higher than in the rest of the sample.

Conclusion. The results point to measurement bias being at least partly responsible for higher blood pressure readings outside the clinic. Automatic measurement devices used for self/home blood pressure measurement seem to cause an alerting reaction analogous to the well-described ‘white coat response’.

Keywords: blood pressure measurement; blood pressure self-measurement; white coat response; primary care; bias.

Introduction

The distinction between the so-called ‘white-coat syndrome’ and ‘true’ or permanent hypertension is now well established in research and in practice. This has been made possible by recent advances in blood pressure measurement technology. Easy-to-operate automatic devices are widely available, and most patients can perform their own measurements without healthcare professionals being present. Continuous ambulatory blood pressure monitoring (ABPM) is an alternative that is, however, not always available outside specialist care.

In the majority of patients, self-measured or ABPM readings are lower than those taken in clinic. However, a substantial proportion of patients also show a reverse pattern, i.e. they have lower blood pressure levels at the clinic than outside. Little is known about this group, who show an ‘inverse white coat response’, as previous research has concentrated on patients with the ‘classical’ white coat pattern and their characteristics compared with established hypertensive subjects.

We studied possible associations between psychological distress and blood pressure in a sample of practice attenders not on blood pressure-lowering drugs. Here, we report on an analysis that addresses the following questions. What proportion of subjects have higher readings at home than in clinic? Do these subjects differ with regard to demographic, clinical, or psychological characteristics?

To obtain a continuous variable describing patients’ reactions to different measurement modes, we calculated the ‘clinic–home blood pressure difference’ (CHBPD) by subtracting home from clinic blood pressure levels. Patients with a ‘negative CHBPD’, i.e. higher readings at home, were compared with the rest of the sample.

Method

Details of the methods used have been reported elsewhere. In brief, patients attending the Department of Family and Community Medicine at Sunnybrook Health Science Centre (North York, Ontario, Canada) for consultation were recruited on a consecutive basis. Subjects were excluded if they were less than 16 years old or on blood pressure-lowering or psychotropic medication.

Before consulting their doctor, eligible patients filled in a questionnaire on demographic and clinical data as well as psychological distress. Clinic blood pressure measurements were taken by the research assistant, in a quiet private room, usually after consultation with a general practitioner (GP). After five minutes’ rest in a sitting position, patients’ blood pressure was measured on the left arm by a desk-model standard mercury device with an appropriately sized cuff (Baumanometer; WA Baum, Copiague, NY, USA). Two more measurements were made after five and 10 minutes. The mean of the last two readings was used for analysis (clinic blood pressure). The research assistant then instructed patients how to carry out self-measurements using a self-inflating oscillometric device (Sunbeam 7650®). After they were familiar with the technique, patients per-
formed one measurement by themselves while still in the clinic. Participating patients were required to take two measurements daily, in the morning and at bedtime, for seven consecutive days and record them in a diary. Before data analysis, we decided that patients had to carry out at least 11 measurements to be included in the analysis. Subjects thus had sufficient time to become familiar with the self-measurement procedure. One reading from day 4 could be substituted for one missing value. Patients were excluded if more than one reading was missing from days 5–7, or if they indicated that they did not follow the protocol, e.g. because of travel or shift work. The CHBPD was calculated by subtracting the mean of the last six home readings from the mean of the second and third clinic reading, for each patient, separately for systolic and diastolic blood pressure.

After calculating the CHBPD for each subject, we dichotomized the sample according to the sign of this variable. Those whose CHBPD was ‘negative’, i.e. who had higher readings at home than in clinic, were compared with those who had a ‘positive’ response. These comparisons were carried out with regard to a number of basic demographic variables and those that have been suggested to be related to blood pressure or blood pressure reactions by previous research, such as age, sex, education (levels according to Canadian schooling system collapsed into three categories), immigration status (born in Canada versus not born in Canada), experience of current symptoms (this question was adapted from the quantitative dimension of the McGill Pain Questionnaire but extended to any symptom the patient was suffering from, not just pain, on a numerical scale from 0 to 6), dichotomized for analysis with 0 = ‘none or slight’, 1 = ‘moderate to severe’), blood pressure levels (grand mean of clinic and home systolic/diastolic blood pressure), body mass index (BMI; kg/m²), and psychological distress (as measured by the General Health Questionnaire, GHQ). We also compared the two groups with regard to the subdomains of the GHQ, i.e. anxiety, feelings of incompetence, depression, difficulty in coping, and social dys-function, which have been identified by previous research. Chi-squared, t- and Wilcoxon rank sum tests were used depending on the scale and distribution of the variables examined. Adjustments were made for multiple testing. To assess concordance between the dichotomous systolic and diastolic CHBPD, the kappa statistic was calculated. Calculations were made using the SAS statistical package.

As mentioned above, the first three readings obtained in the clinic were taken by the standard mercury instrument. For each individual we calculated an ‘expected blood pressure’ taken at the fourth reading. This was derived from a regression equation calculated for each individual based on the first three readings. Blood pressure was regressed on time. The expected blood pressure was subtracted from each subject’s actual fourth reading taken by the automatic device. Intuitively, this provided a measure of an individual’s blood pressure reactivity to the automatic device. Like the other variables mentioned above, the difference in the ‘observed minus expected fourth reading’ was analysed by CHBPD positive/negative. To preserve the continuous nature of the CHBPD variable and to adjust for multiple confounders, we also performed multiple linear regression analyses with the CHBPD as the dependent variable. We entered several independent variables (see Table 4) and the difference in the ‘observed minus expected fourth reading’. Whether the latter made a significant contribution to the model was evaluated by an incremental F-test. These comparisons were performed separately for systolic and diastolic blood pressure.

Results

Patient characteristics

Of 325 eligible patients approached, 251 (75%) agreed to take part. Participants and non-participants did not differ significantly with regard to age (mean 48.8 years versus 49.3 years, t = –0.17, P = 0.86) or to sex (% female: 52 versus 61, χ² = 2.1, P = 0.15). Thirty-seven participants were subsequently excluded because of psychotropic medication use, missing data for home measurement, or irregular lifestyle during the blood pressure self-measuring period. Table 1 gives the demographic and somatic characteristics of the 214 subjects included in the final analyses.

Distribution of the ‘clinic–home blood pressure difference’

As can be seen from Figure 1, a considerable proportion of the sample had higher readings at home than in the clinic, i.e. one third for systolic and nearly one quarter for diastolic pressure. We then examined whether subjects were concordant with their systolic and diastolic CHBPD. To achieve this, we categorized subjects according to whether they had a ‘positive’ or a ‘negative’ CHBPD. As Table 2 shows, agreement was moderate with kappa = 0.498 (P < 0.001). Only two patients had systolic home blood pressures above 140 mmHg with their clinic levels below that threshold. Another patient produced diastolic home readings of more than 90 mmHg, while clinic diastolic levels were less than this.

‘Positive’ versus ‘negative’ CHBPD

Table 1. Patient characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (% female)</td>
<td>51.2</td>
</tr>
<tr>
<td>Age: mean (SD)</td>
<td>48.7 (16)</td>
</tr>
<tr>
<td>Born in Canada (%)</td>
<td>71.2</td>
</tr>
<tr>
<td>Level of education attained (%)</td>
<td></td>
</tr>
<tr>
<td>Not graduated from high school</td>
<td>11.2</td>
</tr>
<tr>
<td>High school</td>
<td>9.8</td>
</tr>
<tr>
<td>College/trade school</td>
<td>29.8</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>32.0</td>
</tr>
<tr>
<td>Postgraduate degree</td>
<td>17.2</td>
</tr>
<tr>
<td>Current smokers (%)</td>
<td>16.0</td>
</tr>
<tr>
<td>Body mass index: mean (SD)</td>
<td>25.5 (4.6)</td>
</tr>
<tr>
<td>Current symptom bothering (%)</td>
<td></td>
</tr>
<tr>
<td>None or mild</td>
<td>72.0</td>
</tr>
<tr>
<td>Distressing/horrible/excruciating</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Figure 1. (a) The systolic clinic–home blood pressure difference.
Among family practice attenders, one third exhibited a systolic ‘inverse CHBPD’, and one quarter a diastolic ‘inverse CHBPD’. An exploratory analysis of these subjects did not show them to differ from the rest of the sample with regard to important demographic, clinical, or psychological variables. However, subjects exhibiting an ‘inverse CHBPD’ differed considerably with regard to their blood pressure reactions to measurement by an automatic machine while still in the clinic.

Our sample consisted of patients attending a large family medicine group practice. We can, therefore, assume that its composition has been influenced by morbidity and attending patterns. However, to generalize our results to other populations may be permitted, as patients were not selected with regard to specific diagnoses or findings. Still, we have to admit that studies replicating the results in other settings are clearly desirable. The reader should also keep in mind that subjects on blood pressure-lowering medication were excluded. Among non-participants, the proportion of women was higher than among participants, although this did not reach the conventional level of statistical significance.

Although, to our knowledge, the ‘negative’ CHBPD or ‘clinic ambulatory blood pressure difference’ has not been investigated explicitly, the proportion of patients exhibiting this phenomenon can be calculated from published reports on the distribution of the white coat response and related measures.3,14–24 Despite considerable variations between studies, the size of this group seems to be far from negligible (a detailed survey of the literature can be obtained from the first author).

How can the findings from our exploratory study be interpreted? A possible explanation would be that, using an automatic self-inflating device, some patients exhibit a specific ‘alerting response’, resulting in a blood pressure rise. Several authors have described phenomena suggesting an ‘alerting response’ of this kind. Prasad et al25 performed ambulatory blood pressure monitoring for 48 instead of the usual 24 hours. They found raised systolic and diastolic readings during the first two hours after monitors had been applied. These blood pressure elevations did not occur on the second day that their subjects were wearing their monitors. The results from a study of the disruptive effect of portable monitors on sleep point in a similar direction.26

Very few studies evaluating the performance of automatic blood pressure measuring devices used sequential designs. The far more common simultaneous comparison method27 cannot
setting rather than being a manifestation of generalized anxiety
or a ‘white coat response’ that seems to be ‘idiosyncratic to the clinic
in this respect, there seems to be a parallel with the ‘classical’
response to automatic blood pressure measurement and demo-
this response was reduced by previous exposure to automatic
found in a study testing a coin-operated measuring device. 29 The
automatic machine. However, the pattern was reversed for dias-
tolic blood pressure.28 Raised systolic blood pressure levels were
in a population-based study with children aged 10
to 13 years, sequential readings by automatic and mercury
to have above average performance characteristics.6
We are confident that the blood pressure-raising effect observed
in our study is independent of the type or brand of device used. For
the purpose of this study, we chose a device that had been shown
to have above average performance characteristics.6
Previous research has demonstrated bias connected with clinic
blood pressure measurement. Our study, however, points to a
bias caused by devices used to obtain blood pressure readings
outside the clinic. We conclude that no presently available mea-
surement method can claim to produce unbiased estimates of
human beings’ blood pressure, nor do we know what the long-
term risk implications of our findings are. The study of blood
pressure measurement in experimental and healthcare settings
remains a challenge.

demonstrate the postulated ‘alerting response’, as the standard
would only reflect the rise in blood pressure caused by the auto-
matic device. In a population-based study with children aged 10
to 13 years, sequential readings by automatic and mercury
devices showed higher systolic blood pressure readings for the
automatic machine. However, the pattern was reversed for dia-
tolic blood pressure.28 Raised systolic blood pressure levels were
found in a study testing a coin-operated measuring device.29 The
authors discussed the apprehension experienced by the patient
when using a device of this kind. In a sequential comparative
study of an automatic and a mercury device, systolic and diastolic
readings taken by the automatic device were higher than those
taken using the standard device.30 For diastolic pressure,
this response was reduced by previous exposure to automatic
blood pressure devices.
In the study presented here, no association between the
response to automatic blood pressure measurement and demo-
graphic, clinical, or psychological variables could be demonstrat-
ed. In this respect, there seems to be a parallel with the ‘classical’
white coat response that seems to be ‘idiodynamic to the clinic
setting rather than being a manifestation of generalized anxiety
or increased reactivity’.31
The noise caused by the electric pump, together with the fact
that a machine and not a human being is inflating the cuff, may
result in discomfort and anxiety that cause a blood pressure reac-
tion of the kind shown above. Devices that require patients to
inflate the cuff themselves may not be a good alternative, as the
physical effort can also bias the result in a subset of patients.

We are confident that the blood pressure-raising effect observed
in our study is independent of the type or brand of device used. For
the purpose of this study, we chose a device that had been shown
to have above average performance characteristics.6

Table 3. Difference observed minus expected fourth reading in clinic by CHBPD category.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Positive CHBPD Median</th>
<th>Negative CHBPD Median</th>
<th>Z</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic</td>
<td>Observed minus expected fourth reading</td>
<td>–2</td>
<td>2.5</td>
<td>3.56</td>
</tr>
<tr>
<td>Diastolic</td>
<td>Observed minus expected fourth reading</td>
<td>–3.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test statistics refer to Wilcoxon rank sum tests, as the variables analysed were not normally distributed.

Table 4. Difference ‘observed minus expected fourth reading in clinic’ — multiple linear regression analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter estimate</th>
<th>Systolic BP Standard error</th>
<th>P</th>
<th>Parameter estimate</th>
<th>Diastolic BP Standard error</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.64</td>
<td>7.13</td>
<td>0.9</td>
<td>–10.3</td>
<td>4.87</td>
<td>0.04</td>
</tr>
<tr>
<td>Age</td>
<td>–1.1</td>
<td>0.06</td>
<td>0.07</td>
<td>0.05</td>
<td>0.04</td>
<td>0.15</td>
</tr>
<tr>
<td>Sex (f = 0, m = 1)</td>
<td>–3.17</td>
<td>1.66</td>
<td>0.06</td>
<td>–1.67</td>
<td>1.1</td>
<td>0.13</td>
</tr>
<tr>
<td>Educationb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dummy no. 1</td>
<td>0.54</td>
<td>1.74</td>
<td>0.8</td>
<td>–0.6</td>
<td>1.67</td>
<td>0.62</td>
</tr>
<tr>
<td>Dummy no. 2</td>
<td>5.34</td>
<td>2.86</td>
<td>0.06</td>
<td>1.67</td>
<td>1.1</td>
<td>0.13</td>
</tr>
<tr>
<td>Born in Canada (yes = 0, no = 1)</td>
<td>1.18</td>
<td>1.77</td>
<td>0.51</td>
<td>–0.25</td>
<td>1.22</td>
<td>0.84</td>
</tr>
<tr>
<td>BP levelsb</td>
<td>0.03</td>
<td>0.07</td>
<td>0.7</td>
<td>0.23</td>
<td>0.07</td>
<td>0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>–0.16</td>
<td>0.19</td>
<td>0.41</td>
<td>–0.2</td>
<td>0.13</td>
<td>0.41</td>
</tr>
<tr>
<td>Current symptom (no = 0, yes = 1)</td>
<td>1.15</td>
<td>1.79</td>
<td>0.52</td>
<td>1.02</td>
<td>1.23</td>
<td>0.41</td>
</tr>
<tr>
<td>GHQ score</td>
<td>–0.05</td>
<td>0.14</td>
<td>0.7</td>
<td>0.08</td>
<td>0.09</td>
<td>0.89</td>
</tr>
<tr>
<td>Observed minus expected fourth reading</td>
<td>–0.32</td>
<td>0.09</td>
<td>0.0007</td>
<td>–0.46</td>
<td>0.07</td>
<td>0.0001</td>
</tr>
<tr>
<td>Variance explained/ incremental F-testb</td>
<td>R²with = 0.15</td>
<td>F = 12.0</td>
<td>0.0007</td>
<td>R²without = 0.02</td>
<td>F = 38.4</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Probability for H0: Parameter = 0. aHighest level, i.e. at least bachelor’s degree, as reference. bGrand mean of clinic and home blood pressure. cTo evaluate whether variable ‘observed minus expected fourth reading' makes a significant additional contribution to explain the variance of the dependent variable.

References

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