Prognostic Value of Home Heart Rate for Cardiovascular Mortality in the General Population

The Ohasama Study

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Background: Recently, the advantages of self-measurement of blood pressure (BP) at home have been recognized. The same advantages could also be applicable to resting heart rate (HR) values assessed at home using a device designed for home BP measurement. However, there have been no studies investigating whether home HR values predict the risk of cardiovascular disease mortality. We therefore investigated the usefulness of HR values in predicting cardiovascular mortality using a device that allowed self-measurement of BP and HR at home.

Methods: The association between the home-measured resting HR and the 10-year risk of cardiovascular mortality was examined in 1780 Japanese individuals ≥40 years of age who had no significant arrhythmias. A Cox proportional hazards model that adjusted for major risk factors was used.

Results: An increase of 5 beats/min in the morning home HR measurement was associated with a 17% increase in the risk of cardiovascular mortality (95% confidence interval 5% to 30%). This relationship was also statistically significant after adjustment for home BP values. Even when home-measured systolic BP was within the normal range (<135 mm Hg), subjects with HR ≥70 beats/min had a higher risk of cardiovascular mortality (relative hazard 2.16, 95% confidence interval 1.21 to 3.85) than those with normal systolic BP and HR values.


Key Words: Heart rate, blood pressure, cardiovascular disease, mortality, population.
and Treatment of High Blood Pressure (JNC VII)\(^7\) and the European Society of Hypertension-European Society of Cardiology guidelines for the management of arterial hypertension\(^8\) have also emphasized the usefulness of home BP measurements. The same advantages could also be applicable to resting heart rate (HR) values assessed at home (home HR) using a device designed for home BP measurement.

To date, however, there have been no studies investigating whether home HR values predict the risk of cardiovascular disease (CVD) mortality and what value should be made into the reference values. For this reason, we carried out a population-based prospective study to clarify the predictive value of home HR values.

**Methods**

**Design**

The present study was a part of a longitudinal observational study of subjects who had been participating in a BP measurement project in Ohasama, Iwate Prefecture, Japan, since 1987.\(^2\)–\(^5\),\(^9\)–\(^11\) The socioeconomic and demographic characteristics of this region and full details of the project have been described elsewhere.\(^9\),\(^10\) The study protocol was approved by the Institutional Review Board of Tohoku University School of Medicine and by the Department of Health of the Ohasama Town Government.

**Study Population**

The selection of study subjects has been described previously.\(^11\) Briefly, the subjects were \( \geq 40 \) years of age and were residents of three of the four regions of Ohasama (\( n = 2716 \)). Hospitalized persons (\( n = 121 \)) as well as persons who had dementia or who were bedridden (\( n = 31 \)) were excluded. Individuals who worked out of town (\( n = 575 \)) were also excluded because the project involved ambulatory BP monitoring. Informed consent to participate in the study was given by 1957 of the 1989 eligible individuals. We have previously confirmed the representativeness of the 1913 subjects who measured their morning home BP on more than three occasions (3 days).\(^11\) For the current analysis, we also excluded 92 more of these subjects from the group of 1913 subjects, because they did not measure their home BP and home HR in both the morning and the evening for at least 3 days. This criterion was based on our previous observation that the average BP value for the first 3 days did not differ significantly from values obtained over the entire study period,\(^9\) and also on the observation that the average home HR value for the first 3 days (morning HR [mean \( \pm \) SD]: 67.8 \( \pm \) 8.7 beats/min) did not differ from the value obtained over the entire study period (67.8 \( \pm \) 7.9 beats/min); indeed, there was a significant correlation between the latter two values (\( r = 0.87, P = .0001 \)).

We also excluded subjects (\( n = 41 \)) with a history of significant arrhythmias (such as atrial fibrillation), sick sinus syndrome, or permanent pacemaker implantation. Therefore, the study population comprised of 1780 individuals (mean age, 60.6 years; men:women, 40:60), representing almost 90% of the total eligible population.

**Home BP and Heart Rate Measurements**

Physicians and public health nurses conducted a health education class to inform the population about home BP and HR recording, taught them how to measure their own BP and HR, and assessed whether the participants were able to measure their own BP correctly. Of the households in the town, 80% attended the class, and public health nurses visited all of the remaining households to provide similar information.\(^9\),\(^10\)

The subjects were then asked to measure and record their BP and HR once every morning and evening for 4 weeks. Morning measurements of BP and HR were made within 1 h of awakening, before breakfast or taking any drugs, with the subjects seated and having rested for at least 2 min. Evening measurements of BP and HR were made similarly just before going to bed. Home BP and HR were measured using HEM401C automatic devices (Omron Healthcare Co., Kyoto, Japan), which use the cuff-oscillometric method\(^12\) to generate a digital display of systolic/diastolic BP and HR values. These devices have been validated previously\(^12\) and satisfy the criteria of the Association for the Advancement of Medical Instrumentation.\(^13\) The circumference of the arm was \(<34\) cm in most cases, so we used a standard arm cuff.

The pulse interval was calculated from the pulse wave, which was detected by a manometer incorporated in the equipment. The HR was calculated as follows: HR (beats/min) = 60/average pulse interval. The home BP and HR values for each individual were defined as the means of all measurements obtained for that person.

**Follow-Up and Data Collection**

Residence in Ohasama Town on December 31, 2001, was confirmed from the residents’ registration cards, which were considered accurate and reliable because they are the basis for the payment of pensions and social security benefits in Japan. The underlying cause of any death was determined from the death certificates and classified according to the recommendations of the *International Classification of Diseases, 10th revision* (ICD-10). The primary outcome was mortality from CVD, defined as death from disease of the circulatory system (ICD-10: I00 to I99). Secondary outcomes were mortality from cerebrovascular disease (ICD-10: I60 to I69) or heart disease (ICD-10: I00 to I52 or I70 to I99), respectively.

Information on possible confounding variables (such as smoking status, overweight, use of antihypertensive medication, and history of cardiovascular disease, hypercholesterolemia, or diabetes mellitus) was obtained from questionnaires sent to each subject at the time of starting
home BP measurement, from records of annual health check-ups, and from medical records held at the Ohasama Prefectural Hospital.

Statistical Analysis

The association between home HR and BP values and mortality risks were estimated from Cox proportional hazards models14 adjusted for major CVD risk factors (smoking status, overweight, use of antihypertensive medication, and history of cardiovascular disease, hypercholesterolemia, or diabetes). Subjects who died of other causes were treated as censored. Variables were compared using the \( \chi^2 \) test or analysis of variance, as appropriate. Differences with a two-tailed \( P \) value <.05 were considered statistically significant. All statistical analyses were performed using SAS software, version 8.2 (SAS Institute, Cary, NC).

Results

Home Heart Rate Measurement

The mean home HR values were 67.3 ± 7.8 beats/min for the morning and 69.1 ± 7.9 beats/min for the evening, whereas mean home systolic/diastolic BP values were 125.2 ± 15.1/75.1 ± 10.0 mm Hg for the morning and 123.2 ± 14.5/73.4 ± 9.5 mm Hg for the evening. A mean of 23.1 ± 6.9 morning and 23.8 ± 6.9 evening home BP measurements were obtained; similarly, a mean of 22.9±7.0 for morning and 23.6 ± 6.7 evening home HR measurements were recorded. Of the 1780 study subjects, 24% were current or ex-smokers, 30% were overweight (body mass index >25 kg/m\(^2\)), and 30% were taking antihypertensive medication. Of the latter, 297 (56%) were receiving calcium antagonists, 107 (20%) were receiving \( \beta \)-blockers, 111 (21%) were receiving diuretics, and 44 (8.2%) were receiving angiotensin-converting enzyme inhibitors. A history of CVD, hypercholesterolemia, or diabetes was recorded in 131 (7%), 283 (16%), and 186 (10%) subjects, respectively.

Table 1 shows the characteristics of the subjects in each quintile, classified on the basis of morning home HR values. The proportion of smokers was higher in the fifth quintile, whereas the values for mean age and mean systolic BP were higher in the first quintile. No significant association was observed between HR values and a history of diabetes, hypercholesterolemia, or cardiovascular disease. The proportion of subjects who were taking antihypertensive medication was higher in the first quintile, although no specific class of antihypertensive drug could account for this difference (data not shown). A similar pattern of characteristics was observed when the quintiles of evening values were examined (data not shown).

Home Heart Rate and Cardiovascular Disease Mortality Risk

The mean duration of follow-up was 10.5 years (maximum 13.9 years). There were 104 CVD deaths (5.8%) and 178 non-CVD deaths (10.0%). Of the 104 CVD deaths, 60 (60%) were due to cerebrovascular disease and 44 (40%) to heart disease. In addition, 35 subjects (2.0%) moved away from the region and were lost to follow-up. Table 2 shows the relationship between home HR values and the CVD mortality risk. The fifth quintile (≥74 beats/min; relative hazard [RH] = 2.61, \( P = .008 \)), the fourth quintile (70 to 74 beats/min; RH 2.54, \( P = .02 \)) of morning HR values were associated with a significantly higher risk of CVD mortality (for linear trend, \( P < 0.001 \)). When analyzed as a continuous variable, an increase of 5 beats/min in morning home HR as a continuous variable was associated with a 17% increase in the overall CVD mortality risk (95% confidence interval [CI] 5% to 30%, \( P = .003 \)) after adjustment for major risk factors. Similar tendencies were also observed for the cerebrovascular mortality risk (20% risk increase per increase of 5 beats/min in morn-
ing HR, 95% CI 4% to 37%, \( P = .01 \) and the heart disease mortality risk (16%; 95% CI 2% to 37%, \( P = .09 \)).

Similarly, evening HR was linearly associated with an increased risk of CVD mortality (17% risk increase per increase of 5 beats/min in HR; 95% CI 5% to 30%, \( P = .004 \)), cerebrovascular mortality (22%; 95% CI 6% to 39%; \( P < .01 \)). However, only weak trends were observed for heart disease mortality (12%; 95% CI –6% to 33%; \( P = .21 \)).

Because we have previously reported that, in this population, home systolic BP had a stronger predictive power for CVD mortality than home diastolic BP,\(^5\) we further examined the effect of home systolic BP on the relationship between home HR and CVD mortality risk. The relationship was essentially unchanged after adjustment for home systolic BP as well as other major risk factors: increases of 5 beats/min in morning and evening HR were associated with 17% (95% CI 5% to 30%, \( P < .01 \)) and 16% (95% CI 4% to 29%, \( P < .01 \)) increases in the CVD mortality risk, respectively.

As the mean age and the proportions of men, smokers, and individuals receiving antihypertensive treatment differed significantly among the quintiles of home HR values (Table 1), we conducted a subgroup analysis based on these characteristics (Table 3). Both morning HR and evening HR values were positively related to the CVD mortality risk without significant interactions with age, sex, smoking status, and antihypertensive treatment.

### Discussion

This prospective cohort study demonstrated an independent association between home-measured HR values and CVD mortality in a representative sample of the general population in Japan. On average, each increase of 5 beats/min in home HR was associated with an approximately 17% higher risk of CVD mortality, which was independent of home BP values and other possible confounding factors. This association was also observed for the risks of mortality due to stroke and heart disease. Furthermore, individuals with high home-measured BP and high home-measured HR had a threefold higher risk of CVD mortality than did individuals with normal levels of both variables. These results suggest that self-measured resting HR and
BP at home are useful parameters for predicting the CVD risk in the general population.

The present results clearly demonstrated that home HR was an independent predictor of the CVD mortality risk. Home HR measurements are usually taken more frequently under more controlled conditions and with less psychological stress than those obtained in a clinical setting. Several studies have reported a positive relationship between clinic HR measurements and CVD mortality after adjustment for BP values, and our results were consistent with those data. However, as we did not measure clinic HR values in the present study population, we could not compare the predictive power of home HR with that of casually measured HR. Nonetheless, in previous studies that treated HR as a continuous variable, an increase of 10 beats/min and an increase of 20 beats/min in clinic HR was reported to be associated with a 23% and a 63% increase in CVD mortality risk, respectively, whereas in the present study an increase of 10 beats/min and an increase of 20 beats/min in morning home HR was more strongly associated with CVD mortality risk (37% and 87%, respectively). These results may reflect the possibility that home HR can detect a high risk of CVD mortality more effectively than clinic HR, probably through its better reproducibility resulting from multiple measurements under stable conditions at home.

When we estimated the CVD risks among groups defined on the basis of combined parameters, even if home-measured systolic BP was within the normal range (<135 mm Hg), subjects with HR ≥70 beats/min had a higher risk of CVD mortality (RH 2.16, 95% CI 1.21 to 3.85) than those with normal systolic BP and HR values. These results confirmed that a certain proportion of subjects who had higher CVD risk were neglected when HR values were overlooked. Therefore, we consider that the informa-

### Table 3. Relationship between morning home heart rate (HR) and cardiovascular disease (CVD) mortality by baseline subgroups

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<td>Younger (40–69 y)</td>
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<td>0.94–1.31</td>
<td>.39</td>
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<tr>
<td>Older (≥70 y)</td>
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<td>1.13</td>
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<td>1.16</td>
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<td>1.12</td>
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Abbreviations as in Table 2
Relative hazards were calculated by Cox proportional hazard model adjusted for age, sex, smoking status, overweight, use of antihypertensive medication, history of CVD, diabetes, hypercholesterolemia and home systolic BP.

### FIG. 1. Home-measured heart rate (HR) and blood pressure (BP) values and the risk of cardiovascular mortality. The relative hazard and 95% confidence interval for cardiovascular mortality associated with each of four groups, defined by a combination of systolic blood pressure (SBP) and HR (in beats/min [bpm]) measured at home in the morning, are shown. The values have been adjusted for age, sex, smoking status, overweight, use of antihypertensive medication, and history of cardiovascular disease, hypercholesterolemia, or diabetes mellitus. Numbers inside the columns indicate 95% confidence intervals.
tion on home HR values should be considered just as important as home BP values.

Our observational study was unable to resolve the issue of whether HR lowering treatments such as β-blocker therapy should be implemented for patients with high HR. The answers to such questions must await large scale, randomized trials of the effects of HR lowering therapy on major causes of morbidity and mortality.

In conclusion, home-measured HR is a strong predictor of the risk of CVD mortality in the general population, and the CVD risk associated with a particular HR value is independent of the home-measured BP value. In this study, a high home HR value was associated with a high risk of CVD, even in normotensive individuals. Moreover, subjects with high home-measured values of both BP and HR showed an extremely high risk of CVD. The HR values obtained at home should be considered just as important as home BP values.

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References