Hypertension Research (2021) 44:1363–1372
https://doi.org/10.1038/s41440-021-00732-z

REVIEW ARTICLE

# Seasonal variation in blood pressure: current evidence and recommendations for hypertension management

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Received: 9 February 2021 / Revised: 25 April 2021 / Accepted: 28 May 2021 / Published online: 6 September 2021


## Abstract

Blood pressure (BP) exhibits seasonal variation, with an elevation of daytime BP in winter and an elevation of nighttime BP in summer. The wintertime elevation of daytime BP is largely attributable to cold temperatures. The summertime elevation of nighttime BP is not due mainly to temperature; rather, it is considered to be related to physical discomfort and poor sleep quality due to the summer weather. The winter elevation of daytime BP is likely to be associated with the increased incidence of cardiovascular disease (CVD) events in winter compared to other seasons. The suppression of excess seasonal BP changes, especially the wintertime elevation of daytime BP and the summertime elevation of nighttime BP, would contribute to the prevention of CVD events. Herein, we review the literature on seasonal variations in BP, and we recommend the following measures for suppressing excess seasonal BP changes as part of a regimen to manage hypertension: (1) out-of-office BP monitoring, especially home BP measurements, throughout the year to evaluate seasonal variations in BP; (2) the early titration and tapering of antihypertensive medications before winter and summer; (3) the optimization of environmental factors such as room temperature and housing conditions; and (4) the use of information and communication technology–based medicine to evaluate seasonal variations in BP and provide early therapeutic intervention. Seasonal BP variations are an important treatment target for the prevention of CVD through the management of hypertension, and further research is necessary to clarify these variations.

**Keywords** Seasonal variation, Environmental factor, Out-of-office blood pressure monitoring, Cardiovascular disease

## Introduction

It is widely known that blood pressure (BP) shows variability due to physical activity, sleep, temperature, and living environments [1]. Several parameters of BP variability involving intraday, day-by-day, and visit-to-visit variation have been reported to be associated with the incidence of cardiovascular disease (CVD) independent of BP levels [2–6]. Seasonal variation in BP is one phenotype of BP variability.

Seasonal variation in BP usually manifests as increased BP in winter and reduced BP in summer. Daytime BP, which includes morning and evening BP levels, has been reported to be higher in winter than in summer based on evaluations of office, ambulatory, and home BP measurements [7–11]. Epidemiological studies have revealed that the incidence of CVD is higher in winter than in summer [12, 13]. Elevated BP levels induced by vasoconstriction as a result of exposure to cold temperatures during winter are thought to be one of the risk factors for increased CVD incidence [7, 12–15]. Environmental factors such as outdoor or indoor temperatures have been reported to be strongly associated with BP levels [13, 16], and these factors may be the main causes of seasonal BP variation. Behavioral factors may also be associated with seasonal changes in BP [7]. Seasonal variation in BP has important clinical implications for the diagnosis and management of hypertension. Especially in hypertensive patients, the assessment of seasonal changes in BP would contribute to the optimal control of BP.

Here, we review the current evidence regarding seasonal variations in BP, and we present the best practices for managing hypertension while taking seasonal variation into consideration.

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## Seasonal variation in daytime blood pressure

Studies using office, ambulatory, and home BP measurements have shown that daytime BP, which includes both morning and evening BP, is higher in winter than in summer [10, 11, 13, 17–21]. Table 1 summarizes the existing findings regarding seasonal variations in office, ambulatory, and home BP. Home BP monitoring has been widely accepted as an effective tool for the management of hypertension [22–24]. Home BP monitoring can provide sustainable and repeatable measurements throughout the year, which is useful for detecting seasonal changes in BP. Several cohort studies have demonstrated that morning home BP is higher in winter than in summer and that the range of differences in home systolic BP (SBP)/diastolic BP (DBP) between winter and summer is 4–7/2–5 mmHg [10, 19, 20]. Kollias et al. performed a meta-analysis of seasonal variation in daytime BP, and they observed that the difference in daytime home BP (95% confidence interval: CI) between winter and summer was 6.1 (5.1, 7.0)/3.1 (2.6, 3.5) mmHg [8]. Investigations using ambulatory BP monitoring (ABPM) showed that the difference in daytime BP between winter and summer was 3–4/2–3 mmHg [17, 18, 25]. In a meta-analysis by Kollias et al., the difference in daytime ambulatory BP between winter and summer was 3.4 (2.4, 4.4)/2.1 (1.4, 2.8) mmHg [8].

## Environmental factors related to seasonal BP variation and the increasing incidence of CVD in winter

Environmental factors including outdoor and room temperature and housing conditions are suspected to play a major role in the mechanisms of seasonal BP variation. Weather-related changes in BP levels—specifically, increases in daytime (especially morning) ambulatory and home BP levels in cold outdoor temperatures—have been described [9, 16]. Saeki et al. reported that daytime ambulatory BP was more strongly associated with indoor temperatures than with outdoor temperatures [26]. A 1 °C increase in the outdoor temperature corresponded to a 0.28–0.40 mmHg decrease in home SBP in a study by Hozawa et al., but an inverse association between outdoor temperature and BP values was evident only during periods with outdoor temperatures >10 °C [20]. Morning home SBP was reported to be associated with the outdoor temperature (°C) ($r = –0.253$, $p < 0.001$) [11]. An association between the indoor room temperature and home BP was also observed [27, 28], and it has been reported that changes in room temperature are more strongly linked to morning home SBP than to evening home SBP (8.2 vs. 6.5 mmHg increase/10 °C decrease, respectively) [29].

The morning BP surge is greater at cold temperatures than at warm temperatures [30]. The sympathetic nervous system and the renin-angiotensin system are activated in the morning, and this activation is generally considered to be the reason for morning BP elevation [31, 32]. Cold temperatures activate sympathetic nervous tone and induce vascular constriction [25, 30]. In winter, therefore, cold temperatures in the morning induce a BP elevation known as a morning surge, which may partly account for the increase in CVD events in winter. Moreover, regarding the association between seasonal BP variation and target organ damage (TOD), our research group has demonstrated that morning home BP was more closely related to TOD parameters (including the urine albumin-to-creatinine ratio [UACR] and level of brain-type natriuretic peptide [BNP]) in winter than in other seasons, but a similar relationship was not observed for evening home BP [21]. This finding indicated that elevated BP in winter might be related to the progression of hypertensive organ damage such as renal dysfunction and heart failure, which would be consistent with the increased incidence of CVD in winter [12, 13, 21].

## Seasonal variation in nighttime blood pressure

Nighttime BP levels exhibit seasonal variation, with higher values in summer than in winter [9, 16, 18, 25, 33–36]. Nighttime ambulatory BP was reported to be a stronger predictor of CVD than daytime ambulatory BP [37, 38], and an association was reported between nighttime BP measured by a home BP device and the incidence of CVD [39]. Therefore, as with daytime BP, the seasonal variation in nighttime BP might be important for the diagnosis and management of hypertension. Earlier studies had focused on daytime BP in seasonal BP variation, but in 2006, Modesti et al. provided the first report that nighttime BP was higher in summer than in winter[16]. In other studies, nighttime ambulatory BP was reported to be higher in summer than in winter, with an SBP difference of 2–4 mmHg [9, 18, 33, 34]. A meta-analysis revealed that the difference in nighttime ambulatory BP between summer and winter was 1.3 (0.2, 2.3)/0.5 (−0.2, 1.8)[8]. Investigations of home BP indicated that nighttime home BP was also higher in summer than in winter, differing by ~5 mmHg between those seasons [35, 36].

Nocturnal BP dipping is also affected by seasonality, with larger dips in winter than in summer [30, 33]. The increased size of the nocturnal BP dip in winter might also be responsible for the increase in the morning BP surge. In a prospective

**Table 1** Studies on the seasonal variation of blood pressure published after the year 2000

| Author | | BP measurement | Study design | *N* | Men, % | Age, yrs | Treated HT, % | Main results |
|---|---|---|---|---|---|---|---|---|
| Madsen | 2006 | Office | Cross-sectional | 16,756 | 45 | NR | NR | $Dif_{W-S}$ *: 3 mmHg by office measurement. Outdoor temperature is related to office BP (SBP elevated 2 mmHg per 10°C decrease of outdoor temperature). |
| Alperovitch | 2009 | | Prospective | 8801 | 39 | 74 | 51 | $Dif_{W-S}$: 8.0 mmHg by office measurement. Outdoor temperature and office BP were strongly correlated in the elderly (>80 years old). |
| Yang L | 2015 | | Cross-sectional | 23,040 | 44 | 61 | 31 | $Dif_{W-S}$: 9 mmHg by office measurement. |
| Cois | 2015 | | Prospective | 9566 | 39 | 36 | 12 | $Dif_{W-S}$: 4.2 mmHg by office measurement. The difference between summer and winter was higher in subjects in the lower socioeconomic class compared to subjects in the higher socioeconomic class. |
| Wang | 2017 | | Cross-sectional | 438,811 | 57 | 43 | NR | The association of outdoor temperature with office BP was stronger in normotensives than in hypertensives. These associations were stronger in men and older individuals. |
| Jehn | 2002 | Ambulatory | Cross-sectional | 333 | 53 | 45 | NR | The difference of ambulatory SBP between the coldest (<3°C) and the hottest (>21°C) outdoor temperature was 3 mmHg over 24-h, 2 mmHg in the daytime, and 4 mmHg in the nighttime. ABP variability was higher under cold outdoor temperature than under warm outdoor temperature. |
| Modesti | 2006 | | Prospective | 6404 | 50 | 59 | NR | The difference between hot and cold outdoor temperature was 5 mmHg by office measurement, 3 mmHg by 24-h ambulatory measurement, and 4 mmHg in morning surge (33.3 mmHg vs. 37.3 mmHg). |
| Hayashi | 2008 | | Prospective | 45 | 40 | 67 | 0 | The difference between wake-up and pre-wake-up (BP difference around wake-up) was 8.7 mmHg higher in winter than summer. |
| Fedecostante | 2012 | | Cross-sectional | 1395 | 53 | 64 | 57 | $Dif_{W-S}$: 1.1 mmHg by 24-h ambulatory (N.S.), 2.4 mmHg by daytime ambulatory, and –2.3 mmHg by nighttime ambulatory measurement. The $Dif_{W-S}$ was higher in uncontrolled hypertensive and non-treated hypertensive patients. Non-dipper status was more prevalent in summer than in winter (61.9% vs. 41.8%). Isolated nocturnal hypertension (elevated nighttime ABP in untreated patients with normal 24-h and daytime ABP) was more prevalent in summer than in winter (15.2% vs. 9.2%). |
| Modesti | 2013 | | Cross-sectional | 1897 | 55 | 63 | 65 | $Dif_{W-S}$: 0.2 mmHg by 24-h ambulatory (N.S.), 3 mmHg by daytime ambulatory, and 4 mmHg by nighttime ambulatory measurement, and 5 mmHg in morning surge. Outdoor temperature and daylight hours were associated with daytime and nighttime ABP. |
| Saeki | 2014 | | Cross-sectional | 868 | 51 | 72 | 45 | 1°C lower indoor temperature was associated with a 0.22 mmHg increment in daytime BP, a 0.18% higher incidence of nocturnal BP dipping, and a 0.34 mmHg increment in sleep-trough morning surge. Nighttime SBP was related to bed-temperature, but not to indoor or outdoor temperature. |
| Nishizawa | 2018 | | Cross-sectional | 412 | 43 | 71 | 100 | $Dif_{W-S}$: 0.3 mmHg over 24-h (NS), 1.7 mmHg in daytime, −1.1 mmHg in nighttime (NS), and 4.5 mmHg in morning. Morning surge was 5 mmHg higher in winter than in summer. |
| Kimura | 2010 | Home | Prospective | 15 | 47 | 79 | 0 | $Dif_{W-S}$: 12 mmHg by morning measurement. |
| Hozawa | 2011 | | Prospective | 79 | 41 | 73 | NR | $Dif_{W-S}$: 6 mmHg by morning measurement. |

**Table 1** (continued)

| Author | | BP measurement | Study design | *N* | Men, % | Age, yrs | Treated HT, % | Main results |
|---|---|---|---|---|---|---|---|---|
| Hanazawa | 2017 | | Prospective | 1649 | 48 | 62 | 100 | $Dif_{W-S}$: 6.7 mmHg by morning measurement. Seasonal variation was assessed using one cycle of the cosine curve in individual BP values. |
| Yatabe | 2017 | | Prospective | 106 | 50 | 69 | 0 | $Dif_{W-S}$: 7.1 mmHg in the average of morning and evening BP. Variability of room temperature (presented as CV) was related to day-by-day HBP variability (CV) ($R = 0.345$, $p < 0.01$). |
| Iwahori | 2018 | | Cross-sectional | 47,572 | 84 | 51 | 39 | $Dif_{W-S}$: 6.8 mmHg by morning measurement and 6 mmHg by evening measurement. |
| Hanazawa | 2018 | | Prospective | 2787 | 60 | 50 | 100 | Seasonal HBP amplitude between summer and winter was associated with cardiovascular outcomes [Reference [45]]. |
| Narita | 2020 | | Cross-sectional | 4267 | 65 | 47 | 79 | $Dif_{W-S}$: 6 mmHg by morning and 5 mmHg by evening measurement. Prevalence of masked hypertension was lower in summer than other seasons. The association between TOD (UACR and BNP) and morning HBP was stronger in winter than other seasons. |
| Stergiou | 2015 | Office, home, ambulatory | Prospective | 60 | 65 | 65 | 100 | $Dif_{W-S}$: 7 mmHg by office, 4.9 mmHg by home, 6.6 mmHg by daytime ambulatory, and –1.2 mmHg by nighttime ambulatory measurement (NS). Seasonal changes in outdoor temperature and the discomfort indices that reflected weather-induced were correlated with seasonal changes in BP. |
| Tabara | 2018 | Nighttime home | Cross-sectional | 4780 | 32 | 59 | 25 | When using a nighttime HBP device (with automatic BP measurements at midnight, 2 am, and 4 am), nighttime home SBP tended to be higher in summer than in winter (4 mmHg). The mean of nocturnal dipping (SBP) was 5.8% in summer and 11.0% in winter. |
| Narita | 2020 | | Cross-sectional | 2544 | 63 | 49 | 83 | When using a nighttime HBP device (with automatic BP measurements at 2 am, 3 am, and 4 am), $Dif_{W-S}$ was −5 mmHg in nighttime, and the prevalence of masked nocturnal hypertension (uncontrolled nighttime HBP in controlled daytime HBP) was higher in summer than other seasons. |

*$Dif_{W-S}$ represents the difference of SBP between winter and summer.

*ABP* ambulatory blood pressure, *BNP* b-type natriuretic peptide, *BP* blood pressure, *CV* coefficient of variation, *HBP* home blood pressure, *NR* not reported, *NS* not significant, *SBP* systolic blood pressure, *TOD* target organ damage, *UACR* urine albumin creatinine ratio.

observational study using ABPM, Nishizawa et al. observed that the morning surge was higher in winter than in summer [40]. Other research groups reported that the prevalence of the non-dipping (or riser) pattern was higher in summer (at ~70–85%) than in winter (at ~45–55%) [9, 33].

## The pathological significance of the elevation of nighttime BP in summer

Although daytime BP increases in response to cold outdoor temperatures, it has been reported that nighttime ambulatory BP increases with warm outdoor temperatures [9, 16]. Decreases in sleep duration and quality may contribute to the increase in nighttime BP in summer. It has been hypothesized that the reduced sleep duration in summer and the mild, heat-induced perturbations in sleep are at least partly responsible for the nighttime BP elevation in summer [7, 9, 34]. Nocturia and sleep-disordered breathing also induce an elevation of nighttime BP [41–44]. The increased intake of fluids and salt in response to sweating and dehydration in summer has also been considered as possible a cause of nighttime BP elevation [35, 45]. However, both the frequency of nocturia and the prevalence of sleep-disordered breathing have been reported to be higher in winter than in summer [46, 47]. It has been suggested that the elevation of nighttime BP in the summertime might not simply be related to sleep disturbances and might instead result from dietary changes in the summer [45].

Moreover, physicians often taper their patients' antihypertensive medications due to their decreased daytime BP in summer, which could contribute to the elevation of nighttime BP [34]. Since ABPM or a home BP device that can take measurements at night should be used to evaluate nighttime BP, the elevation of nighttime BP is often difficult to recognize. In a cross-sectional study using a home device that can measure nighttime BP, our research group demonstrated that the prevalence of masked nocturnal hypertension (i.e., uncontrolled nighttime home BP despite controlled daytime home BP) was higher in summer than in the other seasons. In the same study, advanced age, diabetes, and elevated office BP were revealed to be significant risk factors for masked nocturnal hypertension in a multivariable logistic analysis [36]. Although the total numbers of CVD events such as stroke and coronary artery disease are highest in winter [12], several epidemiological studies have reported that nighttime CVD events occur more frequently in summer than in winter [48, 49]. In a Japanese epidemiological study that assessed seasonal variation in the incidence of each subtype of stroke among 47,782 stroke patients, the incidence rates of non-cardioembolic ischemic stroke (26% in summer vs. 24% in winter, $p < 0.001$) and lacunar stroke (27% in summer vs. 23% in winter, $p < 0.001$) were higher in summer than in winter [48]. Moreover, in a multiethnic and multinational study of 2270 ST-elevation myocardial infarction (STEMI) patients that investigated whether the circadian variation of STEMI onset is altered in the summer season, the difference between diurnal and nocturnal STEMI rates was markedly decreased in summer [49]. From these findings, it appears that nighttime BP might be an important parameter for the prevention of CVD events, especially in summer.

## Seasonal variations in BP and mortality

The seasonal variations in BP can be summarized as follows: (1) daytime BP, especially morning BP, is higher in winter than in summer, and (2) nighttime BP is higher in summer than in winter [7, 8, 50]. Figure 1 illustrates the associations of seasonal BP variation with temperature, CVD events, and other factors such as environmental and behavioral variables. The total number of CVD events is higher in winter than in other seasons, and CVD events occur more often in the morning than in the evening or nighttime [12, 13, 15, 51]. These studies' data demonstrate that there is an association between the seasonal variation in BP and the incidence of CVD. Specifically, elevated BP due to exposure to cold temperatures in winter may be associated with CVD mortality [12, 13, 15]. Regarding weather-related BP changes, Aubiniere-Robb et al. reported that hypertensive patients who exhibited higher BP in response to cold outdoor temperatures had increased all-cause mortality [52]. There are also several studies demonstrating an association between seasonal BP variation and CVD outcomes. Hanazawa et al. reported that the amplitude of the seasonal variation in BP, which they defined as the average of all increases in home BP from summer to winter, was associated with future CVD events. The inverse-variation group (i.e., patients with higher home BP values in summer than in winter) and the larger-variation group (the patients in whom the BP difference between winter and summer was ≥9.1/4.5 mmHg) both exhibited increases in the risk of CVD events compared to the small-variation group (adjusted hazard ratio [HR] in the inverse-variation group = 3.07, 95% CI: 1.44–6.54; adjusted HR in the larger-variation group = 2.02, 95% CI: 1.03–3.97) [53]. Although robust evidence of an association between seasonal BP variation and CVD mortality is still lacking, the larger seasonal BP difference might be related to the increased risk of CVD events.

## The management of hypertension taking seasonal BP variation into consideration

For the suppression of seasonal changes in BP values, we recommend the following measures in the management of

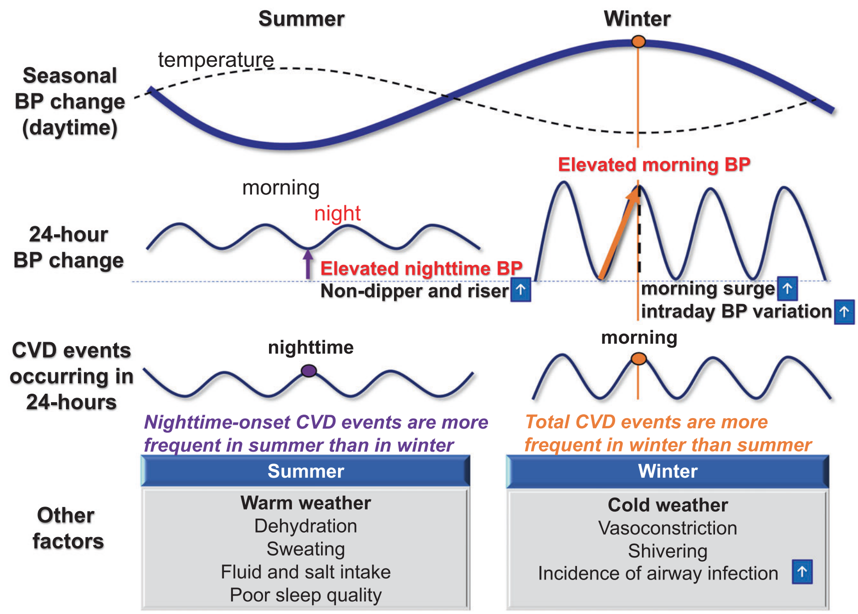


**Fig. 1** Mechanisms of seasonal variation in BP and its association with cardiovascular events

hypertension: (1) home BP measurements throughout the year to evaluate seasonal changes in BP; (2) early adjustment (titration or tapering) of antihypertensive medications; (3) the optimization of environmental factors such as room temperature and housing conditions; and (4) the use of information and communication technology (ICT)-based medicine to evaluate seasonal BP variations and provide early therapeutic intervention. Table 2 provides a summary of these recommendations.

## Home BP monitoring to evaluate seasonal variations in BP

Various international guidelines on hypertension recommend out-of-office BP measurements (including home BP monitoring) in the management of hypertension [22–24]. Home BP monitoring, which has the advantage of sustainable measurement throughout the year as well as accuracy and reproducibility, is useful to evaluate seasonal variations in BP. Several prospective observational studies using home BP monitoring have assessed BP values throughout the year and demonstrated seasonal variation in BP [10, 20, 27, 53]. Although studies using ABPM assessed BP values in summer and winter [9, 16, 34, 40], it may be difficult to assess BP throughout the year due to constraints of ABPM, including the limited availability of monitoring devices and low tolerability among examinees. Our group demonstrated that the prevalence of masked hypertension (office BP < 140/90 mmHg and morning or evening home BP ≥ 135/85 mmHg) was higher in winter than in summer: in winter and summer, 50.6% and 30.5% of patients with controlled office BP had masked hypertension as defined by morning home BP, respectively [21]. The prevalence of white-coat hypertension was higher in summer than in winter (in summer and winter, 37.9% and 25.8% of patients with elevated office BP had white-coat hypertension as defined by morning home BP, respectively) [21]. Although there is not yet sufficient evidence of the superiority of home BP

**Table 2** Recommendations for the management of hypertension with consideration for seasonal variation in blood pressure

| |
|---|
| Using home BP monitoring to evaluate seasonal changes in BP |
| Out-of-office BP monitoring (home or ambulatory) is recommended for the diagnosis and management of hypertension. |
| Home BP monitoring may be useful for the evaluation of seasonal variation of BP. |
| Optimum adjustment of antihypertensive medications |
| Early adjustment of antihypertensive medications<br>- For increasing BP in winter, adjustment of drugs should be conducted in September–November instead of December–February.<br>- For decreasing BP in summer, adjustment of drugs should be conducted in March–May instead of June–August. |
| When BP decreases in summer, SBP < 110–120 mmHg (office, home, or daytime ambulatory) should be carefully considered for tapering antihypertensive medications |
| Optimization of environmental factors |
| The WHO guidelines recommend that optimum room temperature is more than 18°C in winter. |
| Individual patient conditions such as age and sex should be considered when determining the optimum room temperature for winter. |
| Using ICT-based medicine |
| The use of a home BP device equipped with an ICT system may be useful to prevent larger seasonal BP variations such as excessive BP elevation in winter or excessive BP decrease in summer. |

*BP* blood pressure, *ICT* information and communication technology, *SBP* systolic blood pressure.

monitoring to office BP for the evaluation of seasonal BP variations, home BP monitoring might be useful to prevent misdiagnoses of elevated BP in winter and the administration of excessive antihypertensive treatment in summer.

In regard to the prevention of CVD events in winter, our research group demonstrated that morning home BP is associated with the future incidence of CVD events occurring in winter after adjusting for the season when the subjects' baseline BP was measured (adjusted HR per 10 mmHg increase in SBP = 1.22, 95% CI: 1.06–1.42), but this association was not significant for evening home BP [54]. Morning home BP would thus be an important treatment target to prevent the incidence of CVD events in wintertime.

## Early adjustment of antihypertensive medications

In clinical practice, antihypertensive medications are often tapered in summer and titrated in winter in response to seasonal BP changes. Hanazawa et al. reported that the winter-summer difference in home BP was smaller in an early titration group (September–November) than in a late titration group (December–February) (BP changes from summer to winter, 3.9/1.2 mmHg vs. 7.3/3.1 mmHg, $p < 0.001$), and they noted that this difference was also smaller in an early tapering group (March–May) than in a late tapering group (June–August) (BP changes from winter to summer, 4.2/2.1 mmHg vs. 7.1/3.4 mmHg, $p < 0.001$) [53]. In light of these findings, an early adjustment of antihypertensive medications using home BP monitoring would be effective to suppress the amplitude of seasonal BP variations.

Medical practitioners and hypertensive patients should take care to avoid excessive BP decreases in the summer. Although there is no robust evidence in support of specific criteria for the tapering of antihypertensive medications, international guidelines warn against antihypertensive treatment to SBP values <120 mmHg [22–24]. The consensus of the European Society of Hypertension (ESH) working group in regard to seasonal variations in BP is that tapering of antihypertensive medications should be carefully considered in patients with SBP < 110 mmHg (office, home, or ambulatory) [7].

## Optimization of room temperatures

Indoor room temperature has been demonstrated to be related to home BP parameters more strongly than outdoor temperature [26–28, 55]. Saeki et al. reported that instructions on home heating were effective for lowering subjects' BP in a randomized trial [56]. The World Health Organization (WHO) Housing and Health Guidelines recommend that during wintertime, room temperatures be maintained at

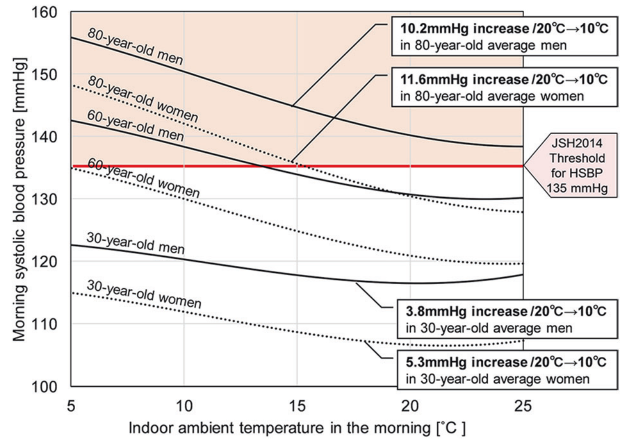


**Fig. 2** Relationship between home BP and room temperature. From Umishio [ref. [19]]

>18 °C [57]. Umishio et al. observed that the indoor ambient temperature at which there is a <50% probability of elevated morning home SBP (≥135 mmHg) is >12 °C for men aged 60 years, >19 °C for men aged 70 years, and >24 °C for men aged 80 years and >11 °C for women aged 70 years and >16 °C for women aged 80 years (Fig. 2) [29]. Based on the results of that study, the optimum room temperature should be decided by taking into account the characteristics of its residents, such as sex and age.

A cohort study in Scotland reported that people in housing heated to <18 °C had a greater risk of elevated BP [58]. In terms of the suppression of the elevation of BP in winter, the WHO's recommendation to maintain room temperatures >18 °C is reasonable.

## Using ICT-based medicine for the management of hypertension with consideration of the seasonal variation in BP

ICT-based medicine may be useful for the management of hypertension with the consideration of seasonal BP variation. Iwahori et al. described the seasonal variation in home BP in a study using home BP data that were automatically collected and simultaneously transmitted electronically to a web-based home BP monitoring platform [11]. Our research group also demonstrated that an ICT-based home BP monitoring system was useful for the evaluation of seasonal BP changes and the adjustment of the dose of antihypertensives, each of which helped patients suppress their seasonal BP amplitudes (Fig. 3) [55, 59, 60]. In the future, BP data obtained by a home, ambulatory, or wearable device could be combined with data on environmental and behavioral factors such as room temperature, sleep duration, and physical activity via an ICT system. These data could then be shared with medical institutions to prevent

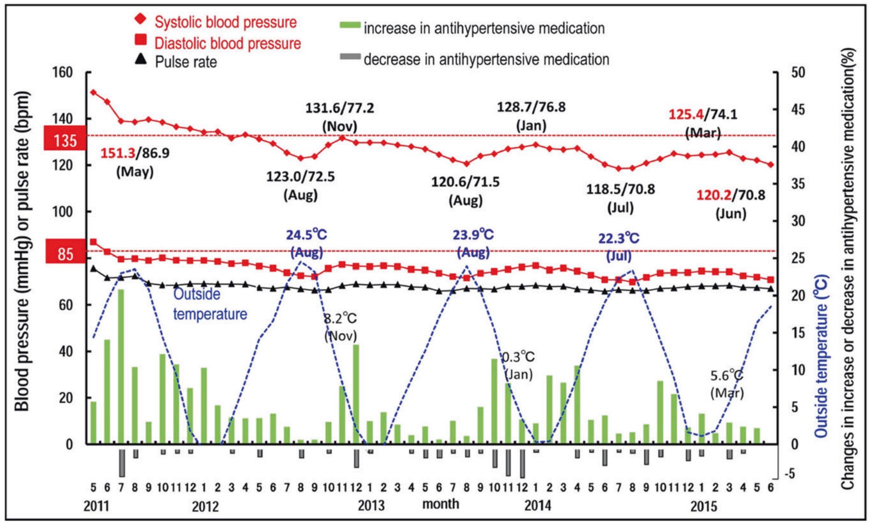


**Fig. 3** Management of hypertension using an information and communication technology (ICT)-based home BP device. Our research group observed that the use of an ICT-based home BP monitoring system helped patients achieve strict BP control and suppress the amplitude of their seasonal BP fluctuations. From Nishizawa [ref. [59]]

excessive seasonal BP changes and reduce the incidence of CVD events [61, 62].

## Conclusions

In the management of hypertension, seasonal variation in BP may be an important treatment target for the prevention of CVD events. In order to assess seasonal variations in BP precisely, out-of-office BP measures such as home BP are recommended. Optimal adjustments of room temperature and the doses of antihypertensive medications should be considered to prevent excess seasonal changes in BP. In addition, ICT-based medicine will be a useful method for managing hypertension while considering seasonal variations in BP. Based on the many reported findings regarding seasonal variations in BP, the pathological significance of seasonal changes in BP is becoming increasingly clear. However, further accumulation of scientific evidence regarding the seasonal variation in BP is needed.

**Author contributions** KK takes primary responsibility for this paper. KN wrote the manuscript. All authors reviewed/edited the manuscript.

## Compliance with ethical standards

**Conflict of interest** KK has received research funding from Teijin Pharma Limited, Omron Healthcare Co., Fukuda Denshi, Bayer Yakuhin Ltd., A&D Co., Daiichi Sankyo Co., Mochida Pharmaceutical Co., EA Pharma, Boehringer Ingelheim Japan Inc., Tanabe Mitsubishi Pharma Corp., Shionogi & Co., MSD K.K., Sanwa Kagaku Kenkyusho Co., and Bristol-Myers Squibb K.K., as well as honoraria from Takeda Pharmaceutical Co. and Omron Healthcare Co.



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