ARTICLE

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Time-series analysis of blood pressure changes after the guideline update in 2019 and the coronavirus disease pandemic in 2020 using Japanese longitudinal data

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Abstract

We assessed blood pressure (BP) changes during fiscal years (April to March of the following year) 2015–2020 to clarify the effect of the state of emergency due to the coronavirus disease 2019 (COVID-19) pandemic in 2020. We then considered BP in 2019 separately, as the Japanese hypertension guidelines were updated in 2019. The present retrospective cohort study extracted data from 157,510 Japanese individuals aged <75 years (mean age: 50.3 years, men: 67.5%) from the annual health check-up data of the DeSC database. The trends in BP were assessed using a repeated measures linear mixed model. After adjusting for the month of health check-ups to exclude seasonal BP variation, systolic BP linearly increased during fiscal years 2015–2018. From the value estimated by the trend in 2015–2018, systolic BP was lower by ≤1 mmHg in fiscal year 2019 among the treated participants. Meanwhile, systolic/diastolic BP (95% confidence interval) increased by 2.11 (1.97–2.24)/1.05 (0.96–1.14) mmHg for untreated women ($n = 43,292$), 1.60 (1.51–1.70)/1.17 (1.11–1.24) mmHg for untreated men ($n = 88,479$), 1.92 (1.60–2.23)/0.46 (0.25–0.67) mmHg for treated women ($n = 7855$), and 1.00 (0.79–1.21)/ 0.39 (0.25–0.53) mmHg for treated men ($n = 17,884$) in fiscal year 2020. These increases remained time-dependent covariates after adjustments for age, body mass index, alcohol consumption, smoking, physical activity, and blood sampling indices. Social change due to the pandemic might have increased BP by approximately 1–2/0.5–1 mmHg. Meanwhile, only a slight decrease in BP was observed immediately after the guideline update in Japan.

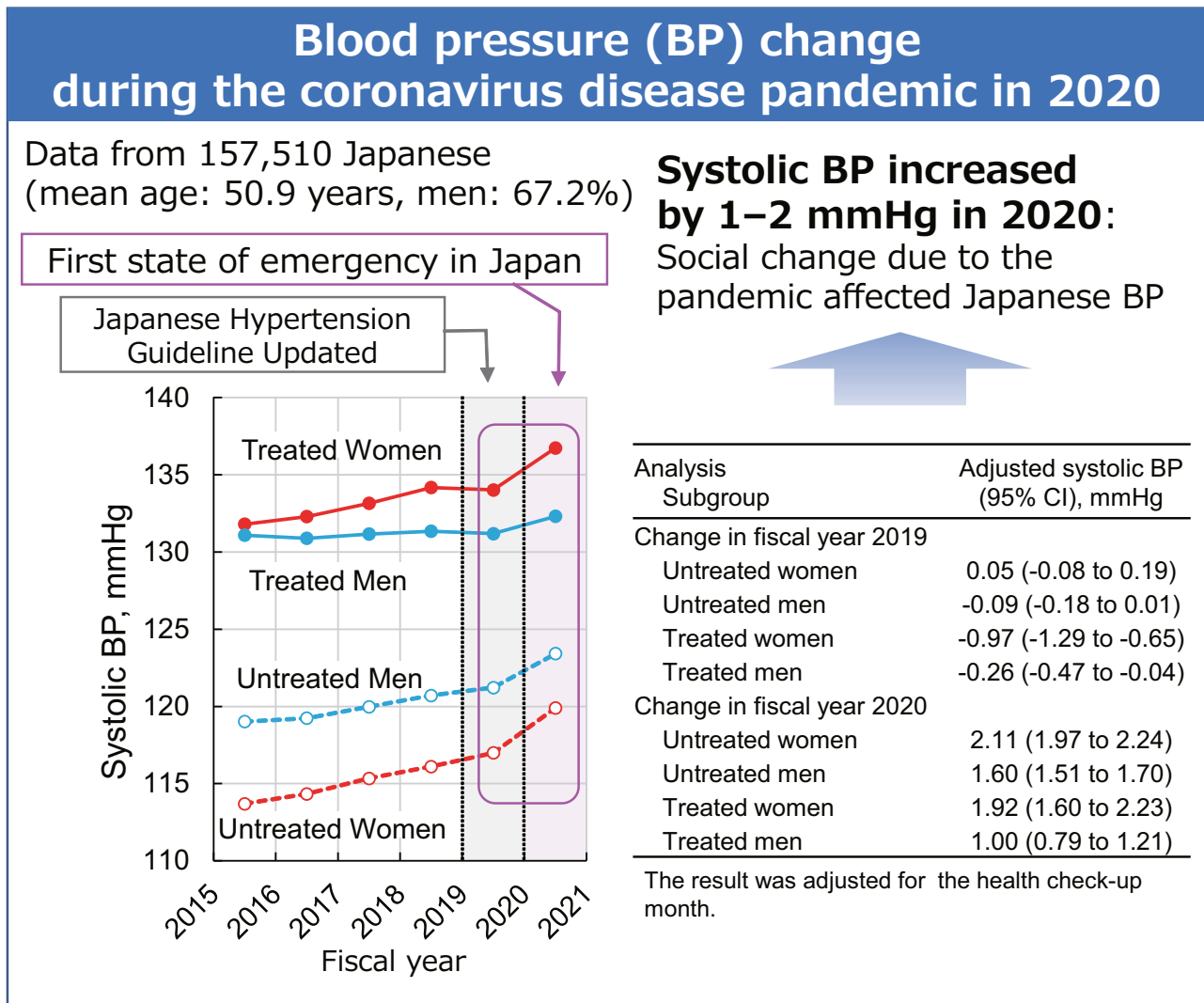**Keywords** Blood pressure · Database · Cohort study · Coronavirus disease pandemic · Epidemiology

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Introduction

Coronavirus disease 2019 (COVID-19) was first identified in late 2019 before its spread worldwide [1]. On 11 March 2020, the World Health Organization declared the COVID-19 outbreak a global pandemic [2]. Many countries introduced lockdowns or restrictions to stop the spread of infection. On 7 April 2020, for the first time, the Japanese government declared a state of emergency, calling on citizens to remain home and refrain from nonessential outings. Most schools and recreational or commercial facilities were closed, and employees were asked to work remotely in Japan; these measures have also been called the "mild lockdown". Previous studies have reported less physical activity in elderly people during the restrictions [3] and the adverse effects of the pandemic on stress, lifestyle habits including smoking behavior, and glycemic control in individuals with diabetes in Japan [4–7]. Changes in diet and weight gain during lockdown have been reported in other

Graphical Abstract

Blood pressure (BP) change during the coronavirus disease pandemic in 2020

Data from 157,510 Japanese
(mean age: 50.9 years, men: 67.2%)

Systolic BP increased by 1–2 mmHg in 2020: Social change due to the pandemic affected Japanese BP

First state of emergency in Japan

Japanese Hypertension Guideline Updated

Analysis Subgroup	Adjusted systolic BP (95% CI), mmHg
Change in fiscal year 2019	
Untreated women	0.05 (-0.08 to 0.19)
Untreated men	-0.09 (-0.18 to 0.01)
Treated women	-0.97 (-1.29 to -0.65)
Treated men	-0.26 (-0.47 to -0.04)
Change in fiscal year 2020	
Untreated women	2.11 (1.97 to 2.24)
Untreated men	1.60 (1.51 to 1.70)
Treated women	1.92 (1.60 to 2.23)
Treated men	1.00 (0.79 to 1.21)

The result was adjusted for the health check-up month.

Point of view

Clinical relevance
Systolic/diastolic BP increased by approximately 1–2/ 0.5–1 mmHg under the state of emergency in fiscal year 2020 among Japanese individuals. The prevalence rates of systolic/ diastolic BP ≥ 130/≥80 mmHg were almost the same between fiscal years 2018 and 2019.
Future direction
We should follow BP trends after 2021 and explore the specific factors associated with the time trends of BP in each Asian population.
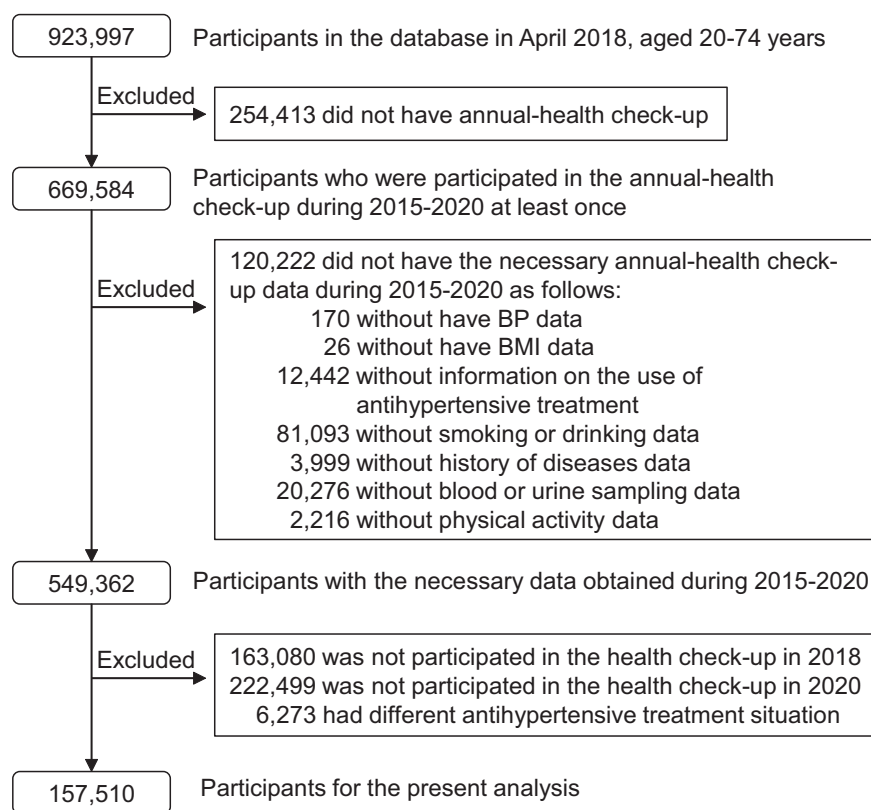**Considerations for Asian populations**
While government measures against the COVID-19 pandemic have varied among countries, it should be noted that BP in an Asian population can be elevated even under a "mild lockdown".

countries [8–12]. However, the results regarding the effects of the restrictions due to the pandemic on BP have been inconsistent [13–18]. A recent study from the United States revealed a mild increase in systolic BP during the COVID-19 pandemic, although only sex, age, and weight gain were considered confounding factors [16]. In contrast, several European studies reported that BP decreased during lockdown [13, 18].

The objective of the present study was to clarify the effect of the state of emergency due to the COVID-19 pandemic in 2020 by assessing the BP changes during the fiscal years (April to March of the following year) 2015–2020 using large-scale annual health check-up data in Japan. Then, we considered BP in 2019 separately since the Japanese Society of Hypertension (JSH) released the new hypertension guideline in April 2019 [19] and lowered target BP by 10 mmHg in most cases [19]. This update may have affected the practice of hypertension treatment.

Fig. 1 Flowchart of participant selection. BP blood pressure

| 923,997 | Participants in the database in April 2018, aged 20-74 years |

Excluded → 254,413 did not have annual-health check-up

| 669,584 | Participants who were participated in the annual-health check-up during 2015-2020 at least once |

Excluded → 120,222 did not have the necessary annual-health check-up data during 2015-2020 as follows:
170 without have BP data
26 without have BMI data
12,442 without information on the use of antihypertensive treatment
81,093 without smoking or drinking data
3,999 without history of diseases data
20,276 without blood or urine sampling data
2,216 without physical activity data

| 549,362 | Participants with the necessary data obtained during 2015-2020 |

Excluded → 163,080 was not participated in the health check-up in 2018
222,499 was not participated in the health check-up in 2020
6,273 had different antihypertensive treatment situation

| 157,510 | Participants for the present analysis |

Materials and methods

Study design and population

We conducted a retrospective cohort study using the DeSC database between April 2015 and November 2020. We used annual health check-up data from the two databases: (1) the Health Insurance Society database, which contains data from Japanese employees and their dependents who are enrolled in health insurance plans run primarily by large-scale enterprises, and (2) the National Health Insurance (NHI) database, which contains data from self-employed, unemployed, or retired persons [20–22]. As it is mandatory for individuals aged ≥75 years to be enrolled in the age-specific health insurance system (late-stage elderly individual medical care insurance), the present study does not have data related to older people. We set the baseline year as fiscal year 2018.

Based on the Ethical Guidelines for Medical and Health Research Involving Human Subjects by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare, Japan, this retrospective study was exempted from obtaining approval from the Institutional Review Board or Ethics Committee as well as individual informed consent since the DeSC data used in this study were unlinked anonymized data. To comply with our contract with DeSC Healthcare Inc., all data and study materials will not be made available to other researchers.

A flowchart of participant selection is shown in Fig. 1. Of the 923,997 participants in the database, 669,584 underwent an annual health check-up during fiscal years 2015–2020 at least once (mean age: 51.9 ± 13.6 years, men: 56.3%). We then excluded participants who did not have the necessary data in fiscal years 2018 and 2020. Furthermore, we excluded participants with different antihypertensive treatment conditions between 2018 and 2020, as they critically affected annual BP changes. Finally, we included 157,510 untreated participants or those treated with antihypertensive drugs in fiscal years 2018 and 2020 in the present analyses.

Data collection

The data were collected at annual health check-ups, which were conducted according to the guidelines set out by the Japanese Ministry of Health, Labour, and Welfare. Information regarding smoking status, alcohol consumption, use of antihypertensive, antidiabetic, and antidyslipidemic drugs, and history of cerebrovascular disease, ischemic heart disease, and kidney disease was gathered using a self-administered questionnaire or interview. For alcohol consumption, the participants were asked to answer questions about their consumption frequency (rarely, sometimes, or everyday). We used data on HbA1c, low-density lipoprotein cholesterol (LDL-c), high-density lipoprotein cholesterol

(HDL-c), triglycerides, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and γ-glutamyl transpeptidase (γ-GTP) from blood sampling. Proteinuria was evaluated using a urine protein dipstick test, and the samples were considered positive for proteinuria when the dipstick test value was ≥1 + (corresponding to a urinary protein level of >30 mg/dL). We defined exercise habits using the question, 'Are you in the habit of exercising to sweat lightly for over 30 min at a time, 2 times a week, for over a year? (Y/N)' and daily physical activity using, 'In your daily life do you walk or do any equivalent physical activity more than one hour a day? (Y/N)'.

The Japanese guidelines for annual health checks recommend measuring BP twice consecutively in a seated position using an automated BP measuring device or sphygmomanometer. To categorize the participants according to BP levels, we used the systolic/diastolic BP threshold of 130/80 mmHg, which is the hypertension threshold in the 2017 ACC/AHA BP guideline [23] and is the target BP among patients with hypertension aged <75 years according to the JSH guideline 2019 [19].

Statistical analysis

The trends in BP and prevalence rate of BP ≥130/≥80 mmHg were assessed using the repeated measures linear mixed model and the logistic generalized linear mixed model with autoregressive order 1 (AR (1)) correlation structure, respectively. AR (1) is a standard method for assessing the covariance matrix in mixed model analyses of longitudinal data [24]. Fiscal year was treated as categorical to assess the detailed BP changes during the fiscal years 2015–2020 (degrees of freedom [DF] = 5). To examine the specific BP changes in fiscal years 2019 and 2020, we used the model including the continuous variable of fiscal year (DF = 1), the code of fiscal year 2019 (=1, other fiscal year =0), and the code of fiscal year 2020 (=1, other fiscal year =0) (the concept of this analysis, study design, and inclusion criteria are shown in Fig. 2). Data on individuals with different antihypertensive treatment statuses from baseline were excluded from all analyses because the use of antihypertensive drugs considerably affected BP values.

In Model 1, the results were adjusted only for the categorical variable of the annual health check-up month (DF = 11) to exclude seasonal BP variation. In Model 2, we added all the characteristics in fiscal year 2018 (baseline), as shown in Table 1. For BP values, the baseline systolic BP or baseline diastolic BP value was added to the model regarding systolic BP changes or diastolic BP changes, respectively. In Model 3, all changeable characteristics assessed in each fiscal year except for BP values, that is, age, body mass index (BMI), smoking, alcohol consumption (rarely/sometimes/everyday), history of ischemic heart disease, history of
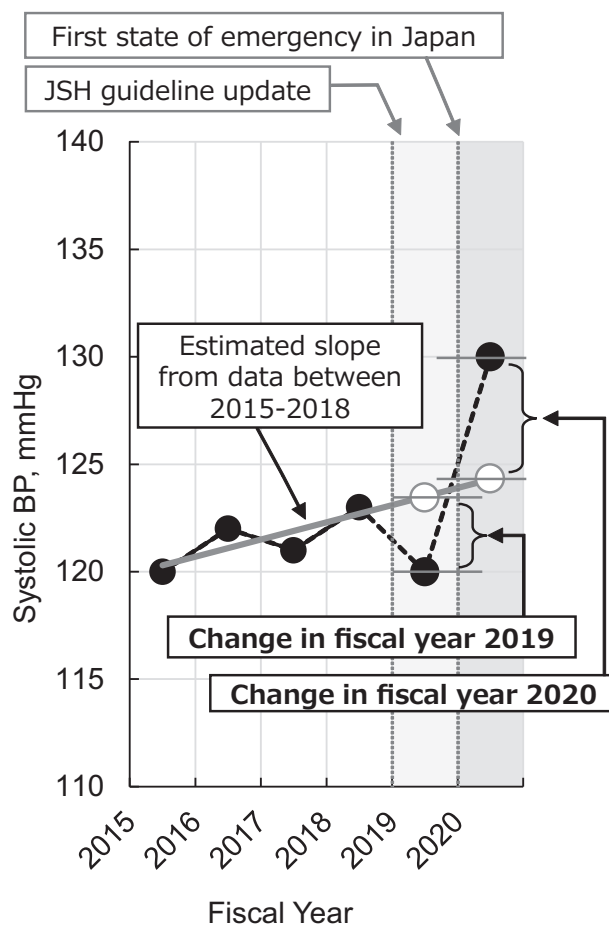

Fig. 2 The schema of the analysis to examine the specific effect of fiscal years 2019 and 2020. We used the model with the continuous variable of fiscal year (DF = 1), the code of fiscal year 2019 (=1, other fiscal year =0), and the code of fiscal year 2020 (=1, other fiscal year =0) to examine this association

stroke, history of kidney disease, proteinuria, the use of antidyslipidemic drugs, triglycerides, LDL-c, HDL-c, the use of antidiabetic drugs, HbA1c, ALT, AST, γ-GTP, exercise habit, and physical activity, were added to Model 2 to assess the results adjusted for time-dependent covariates. Triglycerides, ALT, AST, and γ-GTP were naturally log-transformed because of their positively skewed distributions.

For sensitivity analysis, we conducted stratification analysis according to alcohol consumption or smoking status. Stratification analysis according to age (55 years) was performed for the diastolic BP changes since diastolic BP decreases with aging in an old population [24, 25]. To strictly consider collinearity, we restricted the covariates in the model. Furthermore, we performed an analysis of the participants with all BP data during fiscal years 2015–2020.

All data were analyzed using SAS software (version 9.4; SAS Institute, Cary, North Carolina, USA). Statistical significance was set at $p < 0.05$. Continuous variables are expressed as the mean ± standard deviation unless otherwise noted.

Table 1 Characteristics at baseline (in fiscal year 2018)

Variables	Untreated		Treated	
	Women	Men	Women	Men
N	43,292	88,479	7855	17,884
Age, years	52.2 ± 12.2	46.3 ± 11.9	64.2 ± 7.1	58.9 ± 8.9
BMI, kg/m^2	21.6 ± 3.3	23.2 ± 3.3	23.9 ± 3.9	25.4 ± 3.8
Smoker, %	7.0	29.2	4.1	23.0
Alcohol consumption, %				
Rarely	60.7	31.1	70.5	25.1
Sometimes	29.2	40.4	20.4	31.2
Everyday	10.1	28.5	9.2	43.8
Systolic BP, mmHg	115.7 ± 17.0	120.3 ± 14.2	133.7 ± 16.7	130.9 ± 15.5
Diastolic BP, mmHg	70.0 ± 10.7	75.0 ± 10.6	78.4 ± 10.0	81.4 ± 10.2
History of IHD, %	1.9	1.8	6.6	10.3
History of stroke, %	0.5	0.6	3.8	4.8
History of kidney disease, %	0.4	0.3	1.2	1.6
Proteinuria, %	1.4	2.1	3.0	6.8
Use of antidyslipidaemia drugs, %	9.9	5.8	41.8	32.2
Triglyceride, mmol/L[a]	0.8 (0.6–1.1)	1.0 (0.7–1.5)	1.1 (0.8–1.5)	1.3 (0.9–1.9)
LDL-c, mmol/L	3.1 ± 0.8	3.2 ± 0.8	3.1 ± 0.7	3.0 ± 0.7
HDL-c, mmol/L	1.8 ± 0.4	1.5 ± 0.4	1.7 ± 0.4	1.5 ± 0.4
Use of antidiabetic drugs, %	1.6	2.6	9.3	14.5
HbA1c, %	5.5 ± 0.4	5.5 ± 0.5	5.8 ± 0.6	5.9 ± 0.7
ALT, IU/L[a]	15 (12–19)	21 (16–30)	18 (14–24)	24 (18–35)
AST, IU/L[a]	20 (17–23)	22 (18–26)	22 (19–26)	24 (20–30)
γ-GTP, IU/L[a]	17 (13–23)	29 (20–47)	20 (15–30)	39 (26–66)
Exercise habit, %	36.0	36.5	47.6	45.7
Physical activity, %	45.6	42.8	54.2	44.0
NHI participants, %	35.6	12.2	73.0	35.7

BP blood pressure; *IHD* ischemic heart disease

[a]The values are expressed as median (25th–75th percentiles) because of their positively skewed distributions

Results

Baseline characteristics

The mean age was 50.9 ± 12.3 years, and 67.5% of participants were men. Of the 157,510 participants, 27.9% were untreated women, 56.2% were untreated men, 4.9% were treated women, and 11.0% were treated men. The health check-up participation rates in 2015, 2016, 2017, and 2019 were 58.2%, 75.1%, 82.6%, and 82.6%, respectively (data from fiscal years 2018 and 2020 were not missed because of the participant selection criteria). The data in fiscal year 2020 were collected in summer (June to September) rather than in the other fiscal years (the proportion of summer data: 74.3% in fiscal year 2020 and 48.5–59.4% in the other fiscal years). When compared with the untreated participants group, the treated participants group was older by approximately 12 years and had higher BP levels, and higher proportions of participants with history of diseases,

treatment of diabetes or dyslipidemia, exercise habits and NHI insurees (Table 1).

Change in BP changes during 2015–2020

The detailed systolic/diastolic BP changes during the study period are shown in Fig. 3. After adjustment for the annual health check-up month (Model 1), the systolic BP linearly increased during fiscal years 2015–2018, slightly decreased in fiscal year 2019 only among treated participants and increased by 1–2 mmHg in fiscal year 2020 among all groups. These tendencies seemed to be weak in treated men. Diastolic BP also appeared to increase slightly in fiscal year 2020. The difference in the average systolic BP among the four groups throughout the fiscal period of 2015–2020 was reduced after additional adjustments for baseline characteristics (Model 2). After further adjustments for changeable characteristics during follow-up as time-dependent covariates (Model 3), the
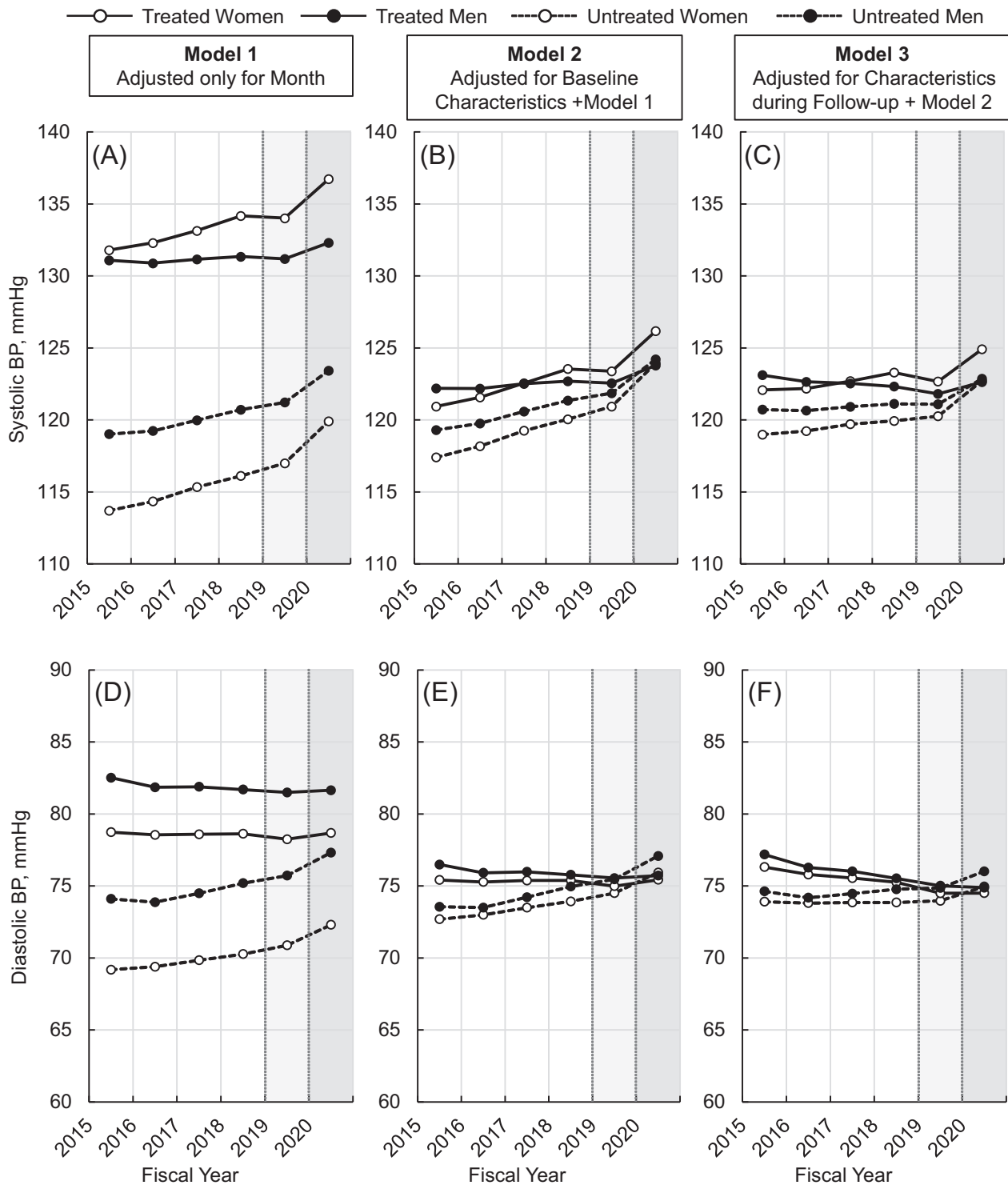
Fig. 3 Detailed changes in systolic BP (**A–C**) and diastolic BP (**D–F**). Model 1 includes the health check-up month (**A, D**). Model 2 includes all baseline characteristics, as indicated in Table 1, in addition to Model 1 (**B, E**). Model 3 additionally includes all characteristics at each health check-up as time-dependent variables (**C, F**). The corresponding 95% confidence intervals are not shown because of the narrow ranges (differences between means and 95% confidence limits ≤ |0.41| mmHg). BP blood pressure

increase in systolic BP in fiscal year 2020 remained, while the positive trends in systolic BP during fiscal years 2015–2018 were attenuated.

When the fiscal year was used as a continuous variable (Table 2), a positive trend in systolic BP between fiscal years 2015 and 2018 was also observed (Model 1 and

Table 2 Systolic BP change during 2015–2020

Analysis subgroup	Systolic BP (95% confidence interval), mmHg		
	Model 1	Model 2	Model 3
Annual change in fiscal years 2015–2018			
Untreated women	0.82 (0.76 to 0.88)[‡]	0.90 (0.85 to 0.94)[‡]	0.33 (0.24 to 0.42)[‡]
Untreated men	0.60 (0.56 to 0.65)[‡]	0.71 (0.67 to 0.74)[‡]	0.15 (0.07 to 0.24)[†]
Treated women	0.82 (0.67 to 0.96)[‡]	0.89 (0.78 to 1.01)[‡]	0.43 (0.29 to 0.56)[‡]
Treated men	0.11 (0.02 to 0.21)[†]	0.19 (0.11 to 0.26)[‡]	−0.24 (−0.35 to −0.14)[‡]
Change in fiscal year 2019[a]			
Untreated women	0.05 (−0.08 to 0.19)	−0.02 (−0.16 to 0.12)	−0.02 (−0.16 to 0.11)
Untreated men	−0.09 (−0.18 to 0.01)	−0.18 (−0.28 to −0.08)[†]	−0.16 (−0.26 to −0.06)[†]
Treated women	−0.97 (−1.29 to −0.65)[‡]	−1.02 (−1.35 to −0.70)[‡]	−1.01 (−1.33 to −0.69)[‡]
Treated men	−0.26 (−0.47 to −0.04)[†]	−0.31 (−0.53 to −0.09)[†]	−0.25 (−0.46 to −0.03)[†]
Change in fiscal year 2020[a]			
Untreated women	2.11 (1.97 to 2.24)[‡]	2.11 (1.98 to 2.24)[‡]	2.13 (2.00 to 2.26)[‡]
Untreated men	1.60 (1.51 to 1.70)[‡]	1.65 (1.56 to 1.75)[‡]	1.62 (1.52 to 1.71)[‡]
Treated women	1.92 (1.60 to 2.23)[‡]	1.90 (1.60 to 2.21)[‡]	1.82 (1.52 to 2.12)[‡]
Treated men	1.00 (0.79 to 1.21)[‡]	1.04 (0.84 to 1.25)[‡]	1.06 (0.86 to 1.27)[‡]

Model 1 includes the health check-up month. Model 2 includes all baseline characteristics indicated in Table 1 (except for diastolic BP), in addition to Model 1. Model 3 includes all changeable characteristics at each health check-up as time-dependent variables, in addition to Model 2

BP blood pressure

[†]$p < 0.05$; [‡]$p < 0.0001$

[a]Changes in BPs were estimated using the method indicated in Fig. 2

Model 2); however, this greatly weakened after adjustments for characteristics during follow-up (Model 3). The distinctive systolic BP changes in fiscal years 2019 and 2020 were almost similar, even after adjustments for time-dependent covariates (Model 3). Regarding the trends in diastolic BP, the distinctive diastolic BP changes in fiscal year 2019 were not obvious (Supplementary Table 1). Meanwhile, the specific change in diastolic BP in fiscal year 2020 (95% confidence interval) was 1.05 (0.96–1.14) mmHg for untreated women, 1.17 (1.11–1.24) mmHg for untreated men, 0.46 (0.25–0.67) mmHg for treated women, and 0.39 (0.25–0.53) mmHg for treated men after adjustments only for the annual health check-up month; these values were similar in Model 2 and Model 3 (Supplementary Table 1).

Sensitivity analysis

A similar increase in systolic BP in fiscal year 2020 was also observed in nonsmokers and participants who rarely consumed alcohol (Supplementary Table 2). When the participants were stratified by the age of 55 years, the diastolic BP increased in fiscal year 2020 regardless of age (0.35–1.20 mmHg) (Supplementary Table 3). We adjusted the systolic BP changes only for NHI participation and the changeable characteristics in each fiscal year without baseline characteristics (sensitivity analysis 1

in Supplementary Table 4). We further restricted the variable characteristics to age, BMI, smoking and drinking status, history of ischemic heart disease, history of stroke, history of kidney disease, proteinuria, LDL-c, HbA1c, γ-GTP, and physical activity in each fiscal year. However, these adjustments did not significantly alter the results (sensitivity analysis 2 in Supplementary Table 4). When the analysis was performed on 65,829 participants who underwent examinations every year during 2015–2020, systolic BP decreased in fiscal year 2019 only among treated women, and the systolic BP increment in fiscal year 2020 among treated women was elevated to 2.68 mmHg (sensitivity analysis 3 in Supplementary Table 4). In this sensitivity analysis, the annual changes for 2015–2018 were comparable to the main results.

The prevalence rate of systolic/diastolic BP ≥130/≥80 mmHg did not significantly change during fiscal year 2018–2019 among treated participants (≈67% for treated women and ≈69% for treated men during fiscal year 2018–2019; Supplementary Fig. 1).

Discussion

Systolic BP increased positively until 2018, but these increments were weakened after adjustment for characteristics during follow-up. In fiscal year 2020, both systolic/

diastolic BP increased by 2.11/1.05 mmHg for untreated women, 1.60/1.17 mmHg for untreated men, 1.92/0.46 mmHg for treated women, and 1.00/0.39 mmHg for treated men. Among the treated participants, a slight decrease in systolic BP was observed in fiscal year 2019, especially in women. These distinctive BP changes in fiscal years 2019 and 2020 did not change after any adjustments for covariates, including time-dependent covariates.

Under a state of emergency, the Japanese population could have been exposed to various stresses, leading to the elevation of BP. In our study, the amplitude of the systolic/diastolic BP increment in fiscal year 2020 was approximately ≤2/≤1 mmHg. This BP elevation could have a great impact on a population while it would be a small change in one individual [19, 26]. Consistent with recent reports from the United States [16], we proved that the systolic BP increase in 2020 persisted after participants were stratified according to antihypertensive treatment status and after adjusting for various confounding factors. Meanwhile, there are several reports indicating different results. Fucile et al. reported that systolic/diastolic BP decreased from 139/78 mmHg to 132/75 mmHg (−7/−3 mmHg) due to the lockdown despite no significant changes in body weight, lipid profile, and blood glucose in 72 patients with hypertension, as observed at a hypertension research center in a university hospital [18]. Pengo et al. showed that in 126 patients with hypertension, home BP decreased by systolic/diastolic BP of 1.8/0.8 mmHg during the COVID-19 outbreak compared to the corresponding time window of the previous year [13]. In their study, patients with hypertension had adequate adherence to treatment and did not show significant body weight variations [13]. It should be noted that these studies were based on patients with hypertension followed at a special medical institution for hypertension [13, 18]. Furthermore, home BP in 535 Japanese treated patients with chronic disease was also reported to decrease during the state of emergency [14]. The subjects in those previous studies might have taken care of their BP levels during lockdown more than other populations [13, 14, 18].

The increase in BP in fiscal year 2020 could have been caused by social changes due to the COVID-19 pandemic. In the present study, most lifestyle changes, such as drinking, smoking status, and physical activity, were not the main factors elevating BP in fiscal year 2020. Other possible factors related to this BP elevation could be mental disorder and changes in salt or potassium intake, since these were not used as covariates in the present study. Rates of major depressive disorder increased during the COVID-19 pandemic in most countries, and women were affected more by the pandemic than men [27]. Between July and October 2020, suicide rates in Japan increased, with a larger increase seen in women than in men [28]. The higher BP among women than that of men in the present study may support

the involvement of mental stress. The systolic BP increment in fiscal year 2020 was 2.13 mmHg for untreated women and 1.82 mmHg for treated women in the present study after adjustments for confounding factors. For treated women, the systolic BP increment in fiscal year 2020 changed to 2.68 mmHg when the participants were restricted to those who underwent an examination every year. Regarding sodium or potassium intake, information regarding nutrients or eating habits in Japan under the state of emergency is inconsistent [29, 30]. Further evidence is needed to confirm the involvement of changes in salt or potassium intake. Temperature did not cause the BP increment in fiscal year 2020 since the present BP data of fiscal year 2020 were specifically collected in the summer season, and the results were adjusted by month. In the present study, the increment of diastolic BP in fiscal year 2020 among treated participants seemed to be smaller than that among untreated participants (approximately 0.4 mmHg vs. 1 mmHg, respectively). The small increase in diastolic BP in fiscal year 2020 among treated participants might have been caused by the lack of vascular elasticity due to the relatively long-term exposure to high BP [24, 25].

Based on our findings, the update of hypertension guidelines in 2019 might have reduced BP in treated patients with hypertension. The target systolic/diastolic BP was lowered from <140/<90 mmHg to <130/<80 mmHg in patients younger than 75 years, according to the JSH guideline 2019 [19]. Systolic BP was reduced by 0.25–1.0 mmHg in fiscal year 2019 among the treated participants. This could reflect the change in physicians' consciousness about BP control due to the JSH guideline update. However, we did not observe any obvious change in the prevalence rate of systolic/diastolic BP ≥ 130/≥80 mmHg during fiscal years 2018–2019, despite the target BP being lowered by the guideline update. This could be due to 'clinical inertia', defined as the failure of health care providers to initiate or intensify therapy according to guidelines [19]. Health care providers should comply with the need to enhance antihypertensive treatment according to the guidelines.

Several limitations of our study should be considered when interpreting the findings. First, the database predominantly contains data on middle-aged Japanese workers aged <75 years who underwent annual health check-ups several times. The participants might have been healthier and more health-conscious than other populations. Therefore, the BP increment in fiscal year 2020 might have been underestimated. Second, the real-world data used in our study were not collected or organized to support research, nor were they optimized for such purposes. However, the present study based on real-world data revealed the real situation in Japan without biases related to clinical trials such as the Hawthorn effect. Third, the present study did not

provide detailed information on antihypertensive drugs and data after 2020. Further studies should wait for the accumulation of data from 2021 onward to predict whether the basic trend in BP over the years will be linear. Fourth, data on alcohol consumption, smoking status, and physical activity were collected through questionnaires or interviews during health check-ups. Adjustments for these variables might not be perfect because of reporting bias.

Perspectives in Asia

A slight decline in BP after the hypertension guideline update was observed in the present study, while the hypertension control rate was reported to decrease during 2013–2018 in the US population [31]. The present study also suggests that the BP in an Asian population can increase even under a "mild lockdown", which was implemented by the Japanese government. Government measures against the COVID-19 pandemic have varied among countries, even among Asian countries. We should follow BP trends after 2021 and explore the specific factors associated with the time trends of BP in each Asian population.

Conclusion

Systolic/diastolic BP increased by approximately 1–2/0.5–1 mmHg under the state of emergency in fiscal year 2020 among Japanese individuals, when most people experienced various social restrictions due to the COVID-19 pandemic. This BP increment was not altered by any adjustments for covariates, including time-dependent variables, such as BMI, alcohol consumption, smoking status, and physical activity. The hypertension guideline update might have been responsible for the slight decrease in BP among the treated patients with hypertension in fiscal year 2019. However, the prevalence rates of systolic/diastolic BP ≥ 130/≥80 mmHg were almost the same between fiscal years 2018 and 2019.

Author contributions MS: Conceptualization, data curation, formal analysis, funding acquisition, methodology, project administration, supervision, validation, visualization, and writing of the original draft. TM: Methodology, project administration, validation, visualization, writing, review, and editing. TO: Methodology, validation, visualization, writing review, and editing. HM: Conceptualization, formal analysis, funding acquisition, methodology, project administration, writing review, and editing. All authors contributed to this scientific work and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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