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Association of pharmacological treatments for hypertension, diabetes, and dyslipidemia with health checkup participation and identification of disease control factors among older adults in Tokyo, Japan

Seigo Mitsutake[a], Tatsuro Ishizaki[a,*], Rumiko Tsuchiya-Ito[a,b], Chie Teramoto[c], Sayuri Shimizu[d], Takuya Yamaoka[a], Akihiko Kitamura[a], Hideki Ito[e]

[a] Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan
[b] Dia Foundation for Research on Ageing Societies, Tokyo, Japan
[c] Division of Health Sciences and Nursing, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan
[d] Institute for Health Economics and Policy, Tokyo, Japan
[e] Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology, Tokyo, Japan

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ABSTRACT

The Japanese government encourages older adults to participate in annual health checkups designed to detect lifestyle diseases such as hypertension, diabetes, and dyslipidemia. However, individuals who are already being treated for these diseases are unlikely to benefit from health checkup participation. This retrospective cohort study of older adults evaluated the associations of pharmacological treatments for these diseases with health checkup participation and identified the disease control factors among patients receiving treatments. Using medical claims data and health checkup data between September 2013 and August 2014 from 820,215 older adults aged ≥ 75 years residing in Tokyo, Japan, we examined the associations between pharmacological treatments and health checkup participation using binary logistic regression analysis. Next, patients receiving pharmacological treatments were categorized into intensive, moderate, or limited disease control based on their blood pressure, hemoglobin A1c levels, and lipid levels; multinomial logistic regression analyses were used to identify the disease control factors. The results showed that patients receiving pharmacological treatments were more likely (odds ratio: 1.374; $P < 0.001$) to participate in health checkups than patients not receiving treatments. Patients with intensive disease control were more likely to be aged ≥ 90 years and use home medical care than patients with moderate control. Our findings suggest that it may be beneficial to shift the focus of health checkups from simply identifying at-risk patients to also supporting disease management. Information obtained from databases that link medical claims and health checkup data may improve evaluations of disease control in older adults and help to streamline healthcare systems.

1. Introduction

Health insurers in Japan are required to offer annual health checkups to their enrollees aged 40–74 years to prevent and reduce the prevalence of lifestyle diseases such as hypertension, diabetes, and dyslipidemia (Okamoto, 2017). These health checkups are designed to identify individuals at high risk of developing the target diseases, and are composed of medical consultations, physical examinations, blood pressure (BP) measurements, urine tests, and blood tests (Okamoto, 2017). Older adults aged ≥ 75 years (hereinafter referred to as older adults) are also offered a similar annual health checkup to identify at-risk individuals (Ouchi et al., 2017). In Tokyo, older adults can undergo this health checkup for a cost of less than 500 yen (< $5) (Tokyo extended association of medical care system for the latter-stage elderly people, 2018). Older adults in Japan accounted for 13% of its population in 2015, and this proportion is expected to rise to 18% by 2025 (National Institute of Population and Social Security Research, 2017). Accordingly, there is an urgent need to design and implement an effective and efficient health checkup system that specifically addresses the major health concerns of this population.

Abbreviations: **BP**, **blood pressure**; **SBP**, **systolic blood pressure**; **DBP**, **diastolic blood pressure**; **LDL-C**, **low-density lipoprotein cholesterol**; **HDL-C**, **high-density lipoprotein cholesterol**; **TC**, **triglycerides**

* Corresponding author at: Human Care Research Team, Tokyo Metropolitan Institute of Gerontology, 35-2 Sakae-cho, Itabashi-ku, Tokyo 173-0015, Japan.
E-mail address: tatsuro@tmig.or.jp (T. Ishizaki).

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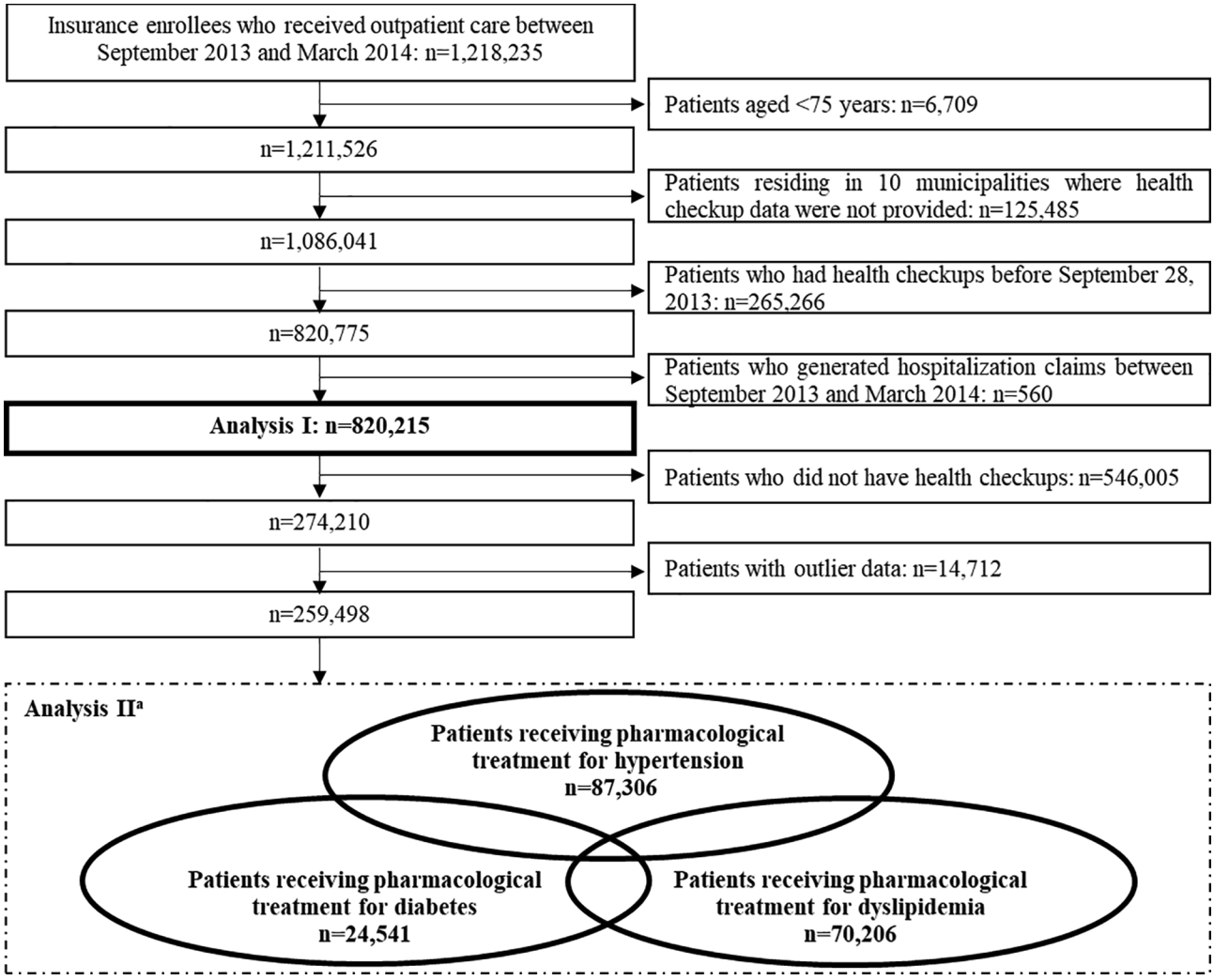

Fig. 1. Flow chart of patient selection. [a]Due to overlaps in pharmacological treatments, the total number of patients receiving each treatment in Analysis II does not add up to 259,498.

Older adults generally have a higher prevalence of hypertension, diabetes, and dyslipidemia than younger people (Barnett et al., 2012; Marengoni et al., 2011; Lochner and Cox, 2013), and are more likely to receive pharmacological treatments for these diseases. The pharmacological treatment rates among older Tokyo residents are approximately 60% for hypertension, 15% for diabetes, and 35% for dyslipidemia (Mitsutake et al., 2019). It is possible that health checkups aimed at the early detection of these diseases in older adults—many of whom are already diagnosed and being treated—would not have any demonstrable benefits. It is therefore important to examine if older adults who undergo annual health checkups are already receiving pharmacological treatments for these diseases. However, little remains known about the associations between these pharmacological treatments in older adults and their participation in annual health checkups.

The Japanese government has highlighted the need for disease management support during annual health checkups for older adults (Ministry of Health, Labour and Welfare, 2018). In many other countries, treatment guidelines for hypertension and diabetes in older adults emphasize balancing treatment with disease burden (James et al., 2014; JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016; Mancia et al., 2014; Qaseem et al., 2018; Rakugi and Yamamoto, 2017). The American College of Physicians advocates that physicians refrain from setting hemoglobin A1c (HbA1c) targets below 7% in most patients with type 2 diabetes, and avoid any HbA1c targets for adults aged ≥ 80 years (Qaseem et al., 2018). Similarly, Japanese treatment guidelines for older patients with diabetes recommend mild glycemic control that takes into account each patient's age, cognitive function, physical function, comorbidities, risk for severe hypoglycemia, and life expectancy (JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016). Furthermore, various countries' guidelines for the management of hypertension in older adults recommend a BP goal of <150/90 mmHg (Mancia et al., 2014; James et al., 2014; Rakugi and Yamamoto, 2017) instead of <140/90 mmHg, which is used for younger adults. Despite these recommendations, the optimal glycemic and BP treatment targets for older adults remain undetermined (Williamson et al., 2016). Monitoring the management of BP, HbA1c, and lipid levels among older adults receiving pharmacological treatments for hypertension, diabetes, and dyslipidemia would be the first step in effectively controlling these diseases. A previous study had evaluated the management of these diseases in adults aged <75 years who underwent health checkups (Miyagawa et al., 2014). However, few studies have focused on the

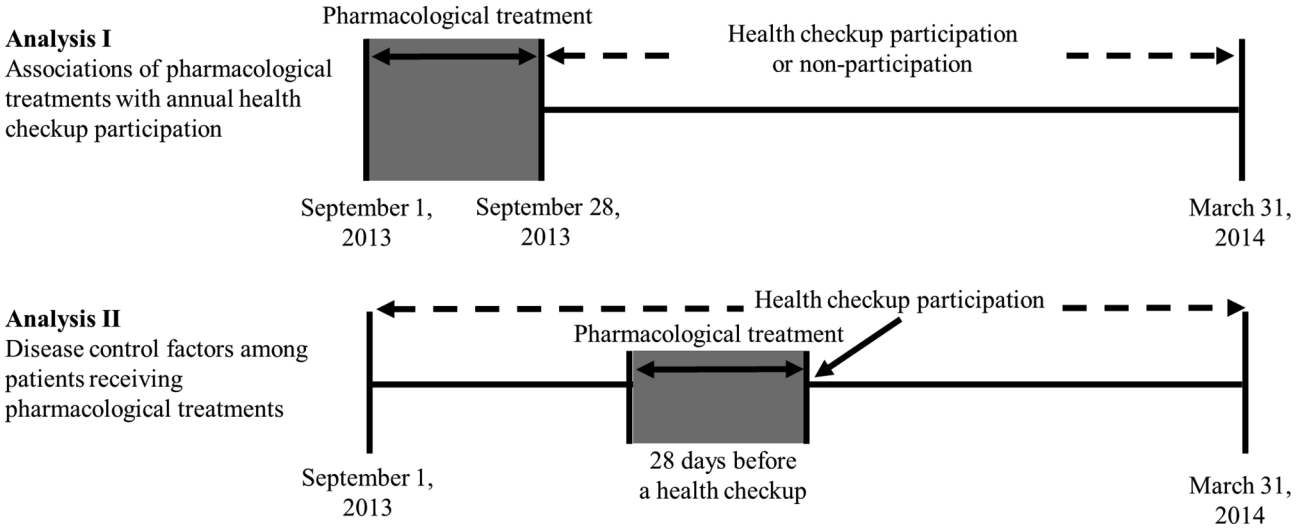

Fig. 2. Definitions of pharmacological treatments for hypertension, diabetes, and dyslipidemia in Analyses I and II.

management of older adults who are already receiving pharmacological treatments for these diseases.

We have previously developed a database that links medical claims data with health checkup data in older adults residing in Tokyo. Here, we present two analyses (designated Analysis I and Analysis II) that utilize this database with the aim of improving the ability of Japan's health checkup system to address and monitor the major health concerns of older adults. In Analysis I, we examined the associations of pharmacological treatments for hypertension, diabetes, and dyslipidemia with health checkup participation in older adults. In Analysis II, we identified the factors associated with disease control for hypertension, diabetes, and dyslipidemia in older adults receiving pharmacological treatments.

2. Methods

2.1. Study design and database

This retrospective cohort study was conducted using a large-scale, anonymized database that combined medical claims data and health checkup data. Medical claims data from September 1, 2013 to August 31, 2014 were obtained from the Tokyo Extended Association of Medical Care for Latter-Stage Older People, which manages the medical insurance program for older adults residing in Tokyo, Japan. Japanese citizens are required to enroll in this insurance program on their 75th birthday. Data were acquired from 1,311,116 individuals (representing 97.1% of a total of 1,350,964 insured persons) for whom medical claims were generated during the study period. The data included patient-level sociodemographic characteristics, treatments, medical facilities used, prescribed drugs, and diagnoses made during clinical encounters.

We were provided health checkup data for the 2013 fiscal year (April 1, 2013 to March 31, 2014) from 52 of the 62 municipalities in Tokyo. These data included measurements for systolic BP (SBP), diastolic BP (DBP), HbA1c, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG). Using individual identification numbers generated for this study, we linked each individual's medical claims data with his/her corresponding health checkup data.

2.2. Patient selection

Fig. 1 shows the patient selection flow chart for Analyses I and II. From 1,218,235 insurance enrollees who had received outpatient care at a hospital or other medical institution between September 2013 and March 2014, we excluded 6709 patients aged <75 years and 125,485 patients who were residing in the 10 municipalities that did not provide health checkup data. We analyzed health checkups that occurred between September 28, 2013 and March 31, 2014. Health checkups are performed once every fiscal year within each municipality at a medical facility for insured patients who reside within that municipality. In this study, we examined the use of pharmacological treatments in each patient during a 28-day period before his/her checkup (if the patient underwent a checkup in Analysis I). As we did not have access to medical claims data before September 1, 2013, we were only able to identify the pharmacological treatments of those who had undergone health checkups on September 28, 2013 or later. Therefore, a total of 265,266 patients who had undergone health checkups before September 28, 2013 were excluded from analysis. Furthermore, 560 patients who were hospitalized between September 2013 and March 2014 were also excluded from analysis because they were less likely to participate in health checkups than non-hospitalized patients. Analysis I was conducted using 820,215 patients.

From the 274,210 patients who had undergone health checkups (Fig. 1), 14,712 patients with non-standard test values (i.e., outlier data) were excluded from analysis. The standard test values were obtained from the health checkup guidelines issued by Japan's Ministry of Health, Labour and Welfare (Ministry of Health, Labour and Welfare, 2019). Analysis II included 87,306, 24,541, and 70,206 patients who received pharmacological treatments for hypertension, diabetes, and dyslipidemia, respectively.

2.3. Definitions of pharmacological treatments for hypertension, diabetes, and dyslipidemia

The definitions of pharmacological treatments for the target diseases in Analyses I and II are presented in Fig. 2. In Analysis I, a pharmacological treatment referred to any relevant therapeutic agent prescribed during the 28-day period from September 1 to 28, 2013. In Analysis II, a pharmacological treatment referred to any relevant

Table 1
Patient characteristics (n = 820,215).

Characteristics		n	%
Sex	Men	309,230	37.7
	Women	510,985	62.3
Age (years)	75–79	335,078	40.9
	80–84	244,567	29.8
	85–89	150,804	18.4
	≥90	89,766	10.9
Copayment rate	10%	699,168	85.2
	30%	121,047	14.8
Home medical care use	No	756,677	92.3
	Yes	63,538	7.7
Number of outpatient facilities visited	1	49,488	6.0
	2–3	318,774	38.9
	4–5	242,931	29.6
	≥6	209,022	25.5
Chronic diseases			
Dementia	No	750,065	91.4
	Yes	70,150	8.6
Osteoarthritis/Spine disorders	No	637,712	77.7
	Yes	182,503	22.3
Cerebrovascular diseases	No	641,812	78.2
	Yes	178,403	21.8
Coronary heart diseases	No	614,565	74.9
	Yes	205,650	25.1
Pharmacological treatment for hypertension, diabetes, and/or dyslipidemia	No	494,802	60.3
	Yes	325,413	39.7

therapeutic agent prescribed within the 28-day period immediately before each patient's health checkup. Accordingly, the pharmacological treatment statuses referred to prescriptions of any relevant therapeutic agent before a health checkup. These agents included antihypertensive agents for hypertension, antidiabetic agents and insulin preparations for diabetes, and hypolipidemic agents for dyslipidemia.

2.4. Categories of disease control for hypertension, diabetes, and dyslipidemia

For the treatment of hypertension, BP was classified as being under (a) intensive control (SBP < 110 mmHg or DBP < 60 mmHg), (b) moderate control (SBP 110–149 mmHg and DBP 60–89 mmHg), or (c) limited control (SBP ≥ 150 mmHg or DBP ≥ 90 mmHg) (Miyagawa et al., 2014; Mancia et al., 2014; James et al., 2014; Rakugi and Yamamoto, 2017).

For the treatment of diabetes, HbA1c levels (as defined by the National Glycohemoglobin Standardization Program) were classified as being under (a) intensive control (HbA1c < 6.0%), (b) moderate control (HbA1c 6.0–6.9%), or (c) limited control (HbA1c ≥ 7.0%) (Qaseem et al., 2018; JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016; Miyagawa et al., 2014; Wang et al., 2015; Yang et al., 2016; Schwartz et al., 2008).

For the treatment of dyslipidemia, lipid levels were classified as being under (a) intensive control (LDL-C < 100 mg/dl), (b) moderate control (LDL-C 100–139 mg/dl), or (c) limited control (LDL-C ≥ 140 mg/dl) (Miyagawa et al., 2014; Araki et al., 2017).

2.5. Other variables

For Analysis I, we included the following covariates: sex, age, insurance copayment rate, home medical care use, number of outpatient facilities visited, and comorbidities. These were selected as potential factors of health checkup participation that are available in medical claims data and previously used in similar adjustment models (Miyagawa et al., 2014; Wang et al., 2015; McDonald et al., 2009; Yoshida et al., 2008). For Analysis II, we included the following covariates: sex, age, insurance copayment rate, home medical care use, number of outpatient facilities visited, comorbidities, and pharmacological treatment. These were selected as potential factors of disease control for hypertension, diabetes, and dyslipidemia based on clinical guidelines and previous studies (JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016; Mancia et al., 2014; McDonald et al., 2009; Miyagawa et al., 2014; Qaseem et al., 2018; Rakugi and Yamamoto, 2017; Wang et al., 2015). We had also included the pharmacological treatments for hypertension, diabetes, and dyslipidemia. For example, we included the pharmacological treatments for diabetes and dyslipidemia for patients receiving pharmacological treatment for hypertension. In Japan's health insurance system for older adults, the copayment rate is set at either 10% or 30%, depending on income. The higher rate is applicable to individuals who have a taxable income comparable to that of the working generation (≥¥1,450,000 per year, or approximately $14,078). Following previously described methods, chronic diseases (dementia, osteoarthritis and spine disorders, cerebrovascular diseases, and coronary heart diseases) were identified based on International Classification of Diseases, Tenth Revision codes and records of the administration of drug classes that are specifically prescribed to treat these diseases in Japan (Mitsutake et al., 2019).

2.6. Statistical analysis

In Analysis I, the chi-squared test was used to compare characteristics between health checkup participants and non-participants. A binary logistic regression analysis was performed to examine the associations between pharmacological treatment statuses and health checkup participation. In the regression analysis, the dependent variable was health checkup participation or non-participation, and the independent variable of interest was pharmacological treatment for the target diseases. All other variables were treated as covariates.

In Analysis II, the chi-squared test was used to compare disease control categories (intensive, moderate, or limited) among patients receiving pharmacological treatments for each specific disease. Multinomial logistic regression analyses were then performed to examine the factors associated with the management of each disease using the disease control categories as the dependent variables (reference: moderate control). We calculated the adjusted odds ratios and 95% confidence intervals for each variable.

P values (2-sided) below 0.05 were considered statistically significant. All analyses were conducted using SPSS version 23.0 (IBM Corp, Armonk, NY, USA).

2.7. Ethical considerations

The study protocol was approved by the Ethics Committee of the Tokyo Metropolitan Institute of Gerontology. We performed all analyses in accordance with the Ethical Guidelines for Medical and Health Research Involving Human Subjects issued by the Japanese government.

3. Results

A total of 820,215 patients were included in Analysis I (Table 1). Women accounted for 62.3% of all patients, and the 75–79 year age group was the largest (accounting for 40.9% of all patients). Approximately 85.2% of patients used the 10% copayment rate, 7.7% of patients used home medical care, and 38.9% visited 2–3 outpatient facilities. Approximately 40% of patients were receiving pharmacological

Table 2
Associations of pharmacological treatments with health checkup participation (n = 820,215).

		Health checkup participants n = 274,210		Health checkup non-participants n = 546,005			Logistic regression analysis that adjusted for all covariatesHealth checkup participation Reference: Health checkup non-participation		
		n	%	n	%	*P* value[a]	AOR	95% CI	*P* value
Pharmacological treatment for hypertension, diabetes, and/or dyslipidemia	No	150,751	30.5	344,051	69.5	<0.001	1.000		
	Yes	123,459	37.9	201,954	62.1		1.374	(1.360–1.388)	<0.001
Sex	Men	99,993	32.3	209,237	67.7	<0.001	1.000		
	Women	174,217	34.1	336,768	65.9		1.089	(1.078–1.100)	<0.001
Age (years)	75–79	116,636	34.8	218,442	65.2	<0.001	1.000		
	80–84	94,002	38.4	150,565	61.6		1.208	(1.194–1.222)	<0.001
	85–89	45,898	30.4	104,906	69.6		0.958	(0.944–0.971)	<0.001
	≥90	17,674	19.7	72,092	80.3		0.653	(0.640–0.665)	<0.001
Copayment rate	10%	234,539	33.5	464,629	66.5	<0.001	1.000		
	30%	39,671	32.8	81,376	67.2		0.946	(0.933–0.959)	<0.001
Home medical care use	No	268,159	35.4	488,518	64.6	<0.001	1.000		
	Yes	6,051	9.5	57,487	90.5		0.239	(0.232–0.246)	<0.001
Number of outpatient facilities visited	1	11,338	22.9	38,150	77.1	<0.001	1.000		
	2–3	83,441	26.2	235,333	73.8		1.313	(1.283–1.344)	<0.001
	4–5	87,262	35.9	155,669	64.1		2.018	(1.971–2.066)	<0.001
	≥6	92,169	44.1	116,853	55.9		2.756	(2.691–2.823)	<0.001
Chronic diseases									
Dementia	No	258,402	34.5	491,663	65.5	<0.001	1.000		
	Yes	15,808	22.5	54,342	77.5		0.694	(0.681–0.708)	<0.001
Osteoarthritis/Spine disorders	No	203,070	31.8	434,642	68.2	<0.001	1.000		
	Yes	71,140	39.0	111,363	61.0		1.072	(1.059–1.085)	<0.001
Cerebrovascular diseases	No	223,877	34.9	417,935	65.1	<0.001	1.000		
	Yes	50,333	28.2	128,070	71.8		0.757	(0.747–0.766)	<0.001
Coronary heart diseases	No	212,167	34.5	402,398	65.5	<0.001	1.000		
	Yes	62,043	30.2	143,607	69.8		0.746	(0.737–0.754)	<0.001

Abbreviation: AOR, adjusted odds ratio; CI: confidence interval.
[a] *P* value: χ^2 test.

treatments for hypertension, diabetes, and/or dyslipidemia. The pharmacological treatment rates were 27.4% for hypertension, 9.3% for diabetes, and 19.7% for dyslipidemia.

3.1. Associations of pharmacological treatments and other variables with health checkup participation

Approximately 38% of patients receiving pharmacological treatment for hypertension, diabetes, and/or dyslipidemia underwent health checkups, and approximately 31% of patients not receiving these

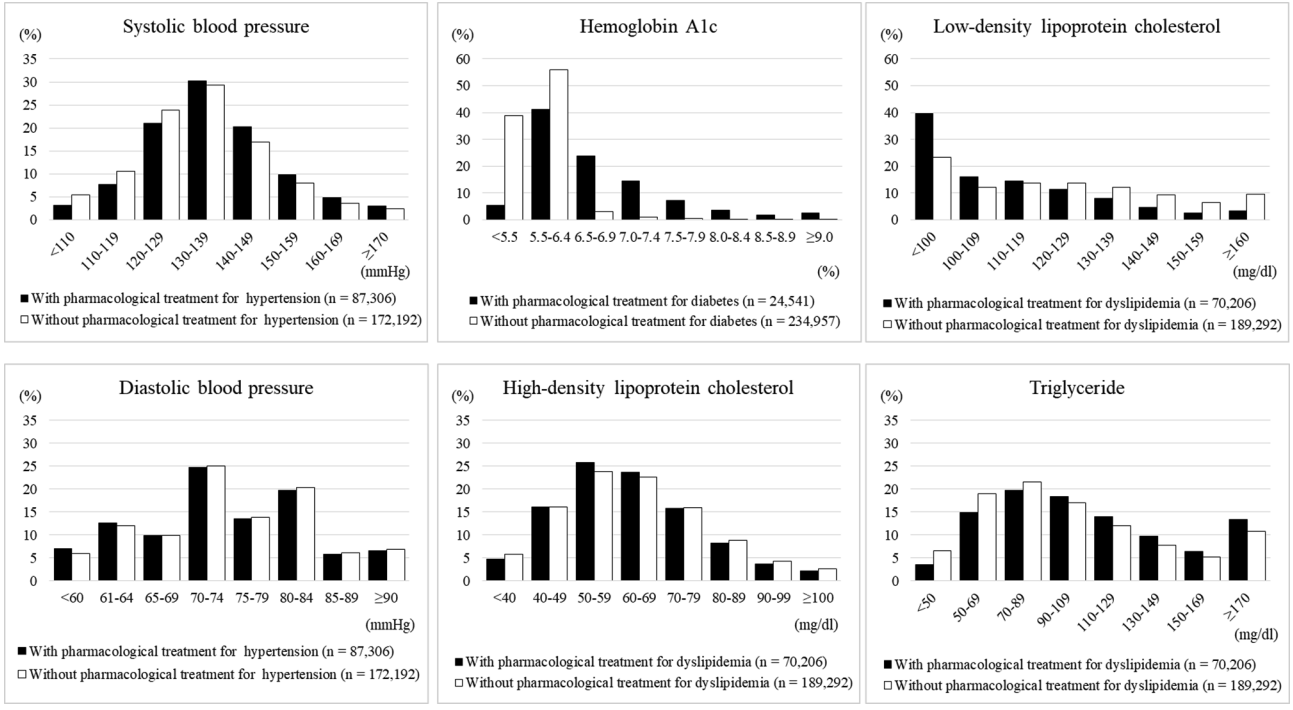

Fig. 3. Distribution of blood pressure, HbA1c level, and lipid levels among health checkup participants.

Table 3
Factors associated with blood pressure among patients receiving pharmacological treatment for hypertension (n = 87,306).

		(a) Intensive control SBP < 110 mmHg or DBP < 60 mmHg n = 2728		(b) Moderate control SBP: 110–149 mmHg and DBP: 60–89 mmHg n = 17,665		(c) Limited control SBP ≥ 150 mmHg or DBP ≥ 90 mmHg n = 66,913			Multinomial logistic regression analysis that adjusted for all covariates Reference: (b) Moderate control			
									(a) Intensive control		(c) Limited control	
		n	%	n	%	n	%	P value[a]	AOR	95% CI	AOR	95% CI
Sex	Men	1,083	3.4	6,352	20.0	24,292	76.6	0.001	1		1	
	Women	1,645	3.0	11,313	20.4	42,621	76.7		0.866	(0.799–0.939)	1.024	(0.988–1.062)
Age (years)	75–79	969	2.9	6,477	19.4	25,959	77.7	<0.001	1			
	80–84	948	3.0	6,275	20.1	23,980	76.9		1.012	(0.923–1.109)	1.065	(1.025–1.108)
	85–89	550	3.3	3,494	21.2	12,405	75.4		1.068	(0.958–1.192)	1.151	(1.098–1.206)
	≥90	261	4.2	1,419	22.7	4,569	73.1		1.279	(1.104–1.481)	1.248	(1.167–1.335)
Copayment rate	10%	2,348	3.1	15,359	20.3	57,809	76.6	0.13	1		1	
	30%	380	3.2	2,306	19.6	9,104	77.2		1.006	(0.900–1.125)	0.963	(0.916–1.012)
Home medical care use	No	2,583	3.0	17,316	20.3	65,522	76.7	<0.001	1		1	
	Yes	145	7.7	349	18.5	1,391	73.8		2.144	(1.781–2.581)	0.886	(0.784–1.000)
Number of outpatient facilities visited	1	50	2.0	622	24.3	1,885	73.7	<0.001	1		1	
	2–3	771	3.0	5,592	21.9	19,130	75.0		1.402	(1.048–1.875)	0.896	(0.814–0.986)
	4–5	879	3.1	5,826	20.4	21,792	76.5		1.438	(1.076–1.922)	0.822	(0.747–0.905)
	≥6	1,028	3.3	5,625	18.3	24,106	78.4		1.541	(1.153–2.060)	0.721	(0.655–0.794)
Chronic diseases												
Dementia	No	2,461	3.0	16,730	20.4	62,968	76.6	<0.001	1		1	
	Yes	267	5.2	935	18.2	3,945	76.6		1.458	(1.272–1.670)	0.863	(0.801–0.930)
Osteoarthritis/Spine disorders	No	2,008	3.2	12,725	20.4	47,617	76.4	0.003	1		1	
	Yes	720	2.9	4,940	19.8	19,296	77.3		0.869	(0.794–0.951)	1.011	(0.972–1.050)
Cerebrovascular diseases	No	1,944	2.9	13,845	20.5	51,752	76.6	<0.001	1		1	
	Yes	784	4.0	3,820	19.3	15,161	76.7		1.247	(1.143–1.360)	0.969	(0.930–1.009)
Coronary heart diseases	No	1,704	2.8	12,763	20.7	47,085	76.5	<0.001	1		1	
	Yes	1,024	4.0	4,902	19.0	19,828	77.0		1.368	(1.262–1.483)	0.927	(0.893–0.963)
Pharmacological treatment												
For diabetes	No	2,335	3.1	14,990	20.1	57,166	76.7	0.144	1		1	
	Yes	393	3.1	2,675	20.9	9,747	76.1		0.960	(0.860–1.072)	1.078	(1.029–1.130)
For dyslipidemia	No	1,651	3.1	11,130	20.9	40,373	76.0	<0.001	1		1	
	Yes	1,077	3.2	6,535	19.1	26,540	77.7		1.007	(0.929–1.091)	0.9	(0.869–0.932)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a] *P* value: χ^2 test.

pharmacological treatments underwent health checkups (Table 2). The results of the binary logistic regression analysis demonstrated that patients who were receiving pharmacological treatments were more likely to participate in health checkups than those not receiving pharmacological treatments (adjusted odds ratio: 1.374, 95% confidence interval: 1.360–1.388, $P < 0.001$). Furthermore, older adults who visited a higher number of outpatient facilities were more likely to undergo health checkups than those who visited only one facility.

3.2. Distribution of BP, HbA1c, and lipid levels in annual health checkup participants

Fig. 3 shows the distribution of BP, HbA1c, and lipid levels among health checkup participants. Among patients receiving pharmacological treatment for hypertension, 17% had SBP ≥150 mmHg (limited control) and 3% had SBP <110 mmHg (intensive control). Among patients receiving pharmacological treatment for diabetes, 30% had HbA1c levels ≥7.0% (limited control) and 45% had HbA1c levels <6.5% (intensive control). Among patients receiving pharmacological treatment for dyslipidemia, 10% had LDL-C levels ≥140 mg/dl (limited control) and 40% had LDL-C levels <100 mg/dl (intensive control).

3.3. Factors associated with BP in patients receiving pharmacological treatment for hypertension

Patients with intensive control of BP were more likely to be men; ≥90 years old; use home medical care; visited more than one outpatient facility for treatment; and have dementia, cerebrovascular diseases, and coronary heart diseases than patients with moderate control (Table 3). In contrast, patients with limited control were more likely to be aged ≥80 years, less likely to have dementia and coronary heart diseases, and less likely to have visited more than one outpatient facility than patients with moderate control.

3.4. Factors associated with HbA1c levels in patients receiving pharmacological treatment for diabetes

When compared with patients with moderate control of HbA1c levels, those with intensive control were more likely to be ≥80 years old, use home medical care, and have osteoarthritis/spine disorders (Table 4). In contrast, patients with limited control were more likely to have dementia, but less likely to have osteoarthritis/spine disorders or to be receiving pharmacological treatment for hypertension.

Table 4
Factors associated with HbA1c levels among patients receiving pharmacological treatment for diabetes (n = 24,541).

		(a) Intensive control HbA1c < 6.0% n = 5102		(b) Moderate control HbA1c: 6.0–6.9% n = 15,998		(c) Limited control HbA1c ≥ 7.0% n = 7234			Multinomial logistic regression analysis that adjusted for all covariates Reference: (b) Moderate control			
									(a) Intensive control		(c) Limited control	
		n	%	n	%	n	%	*P* value[a]	AOR	95% CI	AOR	95% CI
Sex	Men	2,180	19.7	5,533	50.0	3,351	30.3	<0.001	1		1	
	Women	2,922	21.7	6,672	49.5	3,883	28.8		1.068	(0.997–1.145)	0.996	(0.937–1.058)
Age (years)	75–79	1,888	18.1	5,359	51.4	3,176	30.5	<0.001	1		1	
	80–84	1,954	21.9	4,356	48.9	2,601	29.2		1.237	(1.147–1.334)	1.008	(0.944–1.077)
	85–89	932	23.2	1,943	48.5	1,134	28.3		1.276	(1.159–1.405)	0.974	(0.893–1.063)
	≥90	328	27.4	547	45.7	323	27.0		1.546	(1.330–1.798)	0.958	(0.826–1.110)
Copayment rate	10%	4,435	21.0	10,468	49.6	6,184	29.3	0.06	1		1	
	30%	667	19.3	1,737	50.3	1,050	30.4		0.938	(0.850–1.034)	1.012	(0.931–1.101)
Home medical care use	No	4,946	20.7	11,952	49.9	7,050	29.4	0.035	1		1	
	Yes	156	26.3	253	42.7	184	31.0		1.243	(1.008–1.533)	1.192	(0.979–1.452)
Number of outpatient facilities visited	1	128	19.0	321	47.7	224	33.3	<0.001	1		1	
	2–3	1,328	19.4	3,451	50.3	2,082	30.3		0.922	(0.743–1.144)	0.866	(0.723–1.036)
	4–5	1,684	20.5	4,025	49.0	2,510	30.5		0.957	(0.772–1.186)	0.909	(0.760–1.086)
	≥6	1,962	22.3	4,408	50.2	2,418	27.5		0.943	(0.761–1.170)	0.819	(0.684–0.980)
Chronic diseases												
Dementia	No	4,747	20.7	11,490	50.0	6,745	29.3	0.006	1		1	
	Yes	355	22.8	715	45.9	489	31.4		1.116	(0.974–1.279)	1.132	(1.002–1.278)
Osteoarthritis/Spine disorders	No	3,166	18.1	8,817	50.5	5,481	31.4	<0.001	1		1	
	Yes	1,936	27.4	3,388	47.9	1,753	24.8		1.575	(1.464–1.694)	0.856	(0.798–0.918)
Cerebrovascular diseases	No	3,853	20.4	9,457	50.1	5,578	29.5	0.019	1		1	
	Yes	1,249	22.1	2,748	48.6	1,656	29.3		1.081	(0.999–1.169)	1.03	(0.959–1.105)
Coronary heart diseases	No	3,588	20.7	8,571	49.6	5,135	29.7	0.516	1		1	
	Yes	1,514	20.9	3,634	50.1	2,099	29.0		0.984	(0.915–1.059)	0.992	(0.929–1.058)
Pharmacological treatment												
For hypertension	No	2,449	20.9	5,657	48.2	3,620	30.9	<0.001	1		1	
	Yes	2,653	20.7	6,548	51.1	3,614	28.2		0.946	(0.885–1.011)	0.871	(0.821–0.923)
For dyslipidemia	No	3,088	23.2	6,328	47.6	3,875	29.2	<0.001	1		1	
	Yes	2,014	17.9	5,877	52.2	3,359	29.9		0.703	(0.657–0.753)	0.949	(0.894–1.008)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; HbA1c, hemoglobin A1c.
[a] *P* value: χ^2 test

3.5. Factors associated with lipid levels in patients receiving pharmacological treatment for dyslipidemia

When compared with patients with moderate control of lipid levels, those with intensive control were more likely to be men; ≥80 years old; use home medical care; and have dementia, osteoarthritis/spine disorders, cerebrovascular diseases, and coronary heart diseases (Table 5). These patients were also more likely to be receiving pharmacological treatment for hypertension and diabetes. In contrast, patients with limited control were more likely to be women and have dementia than patients with moderate control. Furthermore, patients with limited control were less likely to have cerebrovascular and coronary heart diseases or to be receiving pharmacological treatment for hypertension and diabetes.

4. Discussion

This study integrated health checkup data and medical claims data from Tokyo residents aged ≥75 years to analyze the associations between pharmacological treatments for three major lifestyle diseases and health checkup participation, as well as to explore the factors associated with disease control. The results showed that older adults who were actively receiving pharmacological treatments for hypertension, diabetes, and dyslipidemia were more likely to participate in health checkups than those not being treated. In addition, patients undergoing intensive control in all three target diseases were more likely to be older and to be using home medical care than those undergoing moderate control.

Older adults who were already receiving pharmacological treatments for hypertension, diabetes, and/or dyslipidemia were more likely to participate in health checkups that those not receiving these treatments. Although the Organization for Economic Co-operation and Development has recommended reducing inefficiencies in the Japanese health checkup system (Organisation for Economic Co-operation and Development, 2019), our findings raise questions about the efficiency of having older adults participate in health checkups that are primarily designed to identify individuals at risk of developing these target diseases. The study also revealed that health checkup participants visited more outpatient facilities than non-participants. It has been reported that the greater the number of outpatient facilities visited, the higher the risk of drug-related adverse events (Nobili et al., 2009). It may be possible to modify the health checkup system for older adults so that it can ascertain the statuses of patients' pharmacological treatments and provide this information to their outpatient facilities in order to prevent such adverse events.

Analysis II found that among the older adults receiving pharmacological treatments for the target diseases, those aged ≥90 years and using home medical care were more likely to be undergoing intensive disease control. Cognitive and physical functional statuses decline with progressive aging (Yamada and Arai, 2015), and patients who use home

Table 5
Factors associated with lipid levels among patients receiving pharmacological treatment for dyslipidemia (n = 70,206).

		(a) Intensive control LDL-C < 100 mg/dl n = 27,801		(b) Moderate control LDL-C: 100–139 mg/dl n = 34,970		(c) Limited control LDL-C ≥ 140 mg/dl n = 7,435			Multinomial logistic regression analysis that adjusted for all covariates Reference: (b) Moderate control			
									(a) Intensive control		(c) Limited control	
		n	%	n	%	n	%	*P* value[a]	AOR	95% CI	AOR	95% CI
Sex	Men	9,120	47.4	8,505	44.2	1,628	8.5	<0.001	1		1	
	Women	18,681	36.7	26,465	51.9	5,807	11.4		0.688	(0.663–0.713)	1.123	(1.056–1.194)
Age (years)	75–79	11,045	36.6	15,626	51.8	3,502	11.6	<0.001	1		1	
	80–84	10,220	40.4	12,459	49.3	2,591	10.3		1.121	(1.081–1.162)	0.944	(0.892–0.999)
	85–89	4,942	43.6	5,355	47.2	1,043	9.2		1.234	(1.177–1.293)	0.886	(0.820–0.957)
	≥90	1,594	46.6	1,530	44.7	299	8.7		1.401	(1.298–1.512)	0.878	(0.770–1.001)
Copayment rate	10%	24,010	39.6	30,218	49.8	6,399	10.6	0.732	1		1	
	30%	3,791	39.6	4,752	49.6	1,036	10.8		0.951	(0.908–0.997)	1.039	(0.966–1.118)
Home medical care use	No	27,243	39.4	34,521	49.9	7,350	10.6	<0.001	1		1	
	Yes	558	51.1	449	41.1	85	7.8		1.356	(1.192–1.544)	0.905	(0.713–1.148)
Number of outpatient facilities visited	1	773	38.8	992	49.8	228	11.4	0.001	1		1	
	2–3	7,578	38.5	9,877	50.2	2,208	11.2		0.933	(0.844–1.031)	0.994	(0.854–1.156)
	4–5	9,230	39.8	11,537	49.8	2,410	10.4		0.969	(0.877–1.070)	0.935	(0.804–1.088)
	≥6	10,220	40.3	12,564	49.5	2,589	10.2		0.968	(0.876–1.070)	0.934	(0.802–1.087)
Chronic diseases												
Dementia	No	26,121	39.4	33,204	50.0	7,020	10.6	<0.001	1		1	
	Yes	1,680	43.5	1,766	45.7	415	10.7		1.085	(1.010–1.165)	1.17	(1.045–1.310)
Osteoarthritis/Spine disorders	No	19,524	39.3	24,773	49.9	5,358	10.8	0.007	1		1	
	Yes	8,277	40.3	10,197	49.6	2,077	10.1		1.054	(1.016–1.093)	0.957	(0.903–1.014)
Cerebrovascular diseases	No	21,039	38.0	28,122	50.9	6,142	11.1	<0.001	1		1	
	Yes	6,762	45.4	6,848	46.0	1,293	8.7		1.187	(1.142–1.235)	0.902	(0.844–0.964)
Coronary heart diseases	No	18,063	36.5	25,748	52.0	5,737	11.6	<0.001	1		1	
	Yes	9,738	47.1	9,222	44.6	1,698	8.2		1.369	(1.322–1.418)	0.873	(0.822–0.927)
Pharmacological treatment												
For hypertension	No	12,895	35.8	18,756	52.0	4,403	12.2	<0.001	1		1	
	Yes	14,906	43.6	16,214	47.5	3,032	8.9		1.243	(1.203–1.283)	0.823	(0.782–0.866)
For diabetes	No	22,438	38.1	29,974	50.8	6,544	11.1	<0.001	1		1	
	Yes	5,363	47.7	4,996	44.4	891	7.9		1.34	(1.284–1.399)	0.845	(0.782–0.912)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; LDL-C, low-density lipoprotein cholesterol.
[a] *P* value: χ^2 test.

medical care are presumed to have lower functionalities that render them unable to attend outpatient facilities. With consideration to functional decline in older persons, treatment guidelines for hypertension and diabetes recommend using less intensive clinical measures for this group than for younger patients (JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016; Rakugi and Yamamoto, 2017). Nevertheless, our results indicated that hypertension and diabetes were intensively controlled in older adults with declining cognitive and physical function, which is not concordant with treatment guidelines (JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016; Rakugi and Yamamoto, 2017). It has been pointed out that evaluating cognitive and physical functional statuses in an outpatient setting is difficult due to consultation time constraints (JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016). The inability to accurately evaluate patients' functional statuses in an outpatient setting may have contributed to the intensive management of BP and HbA1c observed in our subjects. The current health checkup system could benefit from the inclusion of functional status evaluations for older adults, with results provided to outpatient medical facilities to make it easier for the attending physicians to manage treatments.

The use of insulin preparations and sulfonylurea drugs for diabetes is associated with an elevated risk of hypoglycemia. As a preventive measure, the recommended lower limit for HbA1c is set at 7.0% (JDS and JGS joint committee on improving care for elderly patients with diabetes, 2016). However, approximately 30% (7234/24,541) of the older adults receiving pharmacological treatment for diabetes in our study had their HbA1c managed to a level below 7.0%. Further studies are needed to ascertain the prevalence and appropriateness of insulin preparation and sulfonylurea drug use among older diabetic patients with aggressively controlled HbA1c values (<7.0%) to examine hypoglycemia prevention strategies.

This study has several limitations. First, the determination of whether or not a patient was receiving pharmacological treatment was based on the number of prescription days within a 28-day period. Patients receiving treatments for more than 28 days were not regarded as receiving pharmacological treatment, which may have led to an underestimation of these patients. We conducted an additional sensitivity analysis using a 35-day period for pharmacological treatment to assess the effects of patients with longer-term prescriptions on our findings. The results for both analyses were similar to the study's main results, which indicated that the inclusion of patients with longer prescriptions would have little effect on our conclusions. Second, the health checkups were conducted at medical facilities, and the BP estimates may be susceptible to the "white coat" effect. As a result, the numbers of people with intensive and limited control of BP may have been underestimated and overestimated, respectively, in Analysis II. Third, the study included only older adults living in Tokyo. Approximately 52% of older adults in Tokyo participate in health checkups, which is substantially higher than the national average of

25% (Tokyo extended association of medical care system for the latter-stage elderly people, 2018). This may limit the generalizability of our findings. Fourth, education level was not included in the analysis as it was not available in the claims data or health checkup data. This increases the risk of residual confounding in our analysis. Because education level may be associated with lower pharmacological treatment (McDonald et al., 2009) and increased health checkup participation (Yoshida et al., 2008), the positive associations between pharmacological treatments and health checkup participation may have been overestimated in Analysis I. However, the copayment rate has been reported to be associated with education level (The Japan Institute for Labour Policy and Training, 2015), and the inclusion of the former in Analysis I may have allowed for some degree of adjustment for the latter. Finally, the subjects for Analysis II were all extracted from the health checkup participants in Analysis I. Users of home medical care are less likely to participate in health checkups, and residents of long-term care facilities were not included in this study. Therefore, the subjects in Analysis II may have been biased toward older adults with relatively good cognitive and physical functional statuses. Nevertheless, the lack of an ideal comprehensive data source means that our approach of linking medical claims data and checkup data may represent the best available option for monitoring the pharmaceutical management of hypertension, diabetes, and dyslipidemia.

5. Conclusion

Our study demonstrated that older adults receiving pharmacological treatments for hypertension, diabetes, and dyslipidemia were more likely to participate in health checkups. This suggests that it may be inefficient to conduct health checkups simply aimed at identifying older adults at risk of developing these diseases. It may be beneficial to consider the modification of these checkups to provide active feedback to each patient's outpatient clinic and facilitate disease control monitoring. In addition, hypertension and diabetes were found to be more intensively controlled in older adults despite reduced cognitive and physical function, which contravenes treatment guidelines. The linkage of claims data and health checkup data may enable the monitoring of chronic disease management in older adults, and our findings may contribute to the evaluation and improvement of the health checkup system.

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Author Contributions

TI, SM, and HI formulated the research question. TI, HI, and SS collected data. TI, SS, CT, and SM developed the database. SM, TI, CT, RT and YT designed and conducted the analysis. All authors interpreted the results. SM drafted the manuscript. All authors critically reviewed the manuscript and approved the final version.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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