Advance Publication

Circulation Journal
doi:10.1253/circj.CJ-22-0095

ORIGINAL ARTICLE

Trends and Factors Associated With Cardiac Rehabilitation Participation

— Data From Japanese Nationwide Databases —

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Background: Few studies have comprehensively evaluated the trends and factors associated with CR participation across major cardiovascular diseases in Japan.

Methods and Results: This study performed a nationwide cross-sectional study using the National Database of Health Insurance Claims and Specific Health Checkups of Japan and the Japanese Registry of All Cardiac and Vascular Diseases and the Diagnosis Procedure Combination database. This study described the nationwide trends and evaluated patient- and hospital-level associated factors of CR participation for patients with acute heart failure (AHF), acute coronary syndrome (ACS), acute aortic dissection (AAD), peripheral artery disease (PAD), and after cardiovascular surgery using mixed-effect logistic regression analysis. Although the annual number of patients who underwent CR has increased during the study period, the total number of patients participating in outpatient CR was lower than that of inpatient CR. The outpatient CR participation rate was lower for patients with AHF (3.5%), AAD (3.2%), and PAD (1.7%), compared with ACS (7.9%) and after surgery (9.4%). Age, sex, body mass index, Barthel index, Charlson comorbidity index, and institutional capacity were identified as significant associated factors of CR participation in inpatient and outpatient settings.

Conclusions: Participation in outpatient CR was still low, and higher age, multi-comorbidity, and low institutional capacity contributed to the lower outpatient CR participation rate. Identification of the associated factors may help cardiologists to increase CR participation.

Key Words: Acute aortic disease; Acute coronary syndrome; Acute heart failure; Cardiac rehabilitation; Cardiovascular surgery

Despite considerable advancement in pharmacological and procedural therapies, cardiovascular diseases are still the major causes of morbidity and mortality worldwide.[1,2] In 2020, cardiovascular diseases were the second leading cause of death in Japan, accounting for about one-quarter of total deaths.[3] Cardiac rehabilitation (CR) is an evidence-based intervention that is associated with a reduction in mortality, rehospitalization, and improved quality of life, in patients with cardiovascular diseases such as acute coronary syndrome (ACS) and acute heart failure (HF).[4,5] CR is a multidisciplinary intervention to prevent recurrent events, including patient assessment, exercise therapy, optimizing medical therapies, dietary modification, and psychological counseling. The delivery of these comprehensive CR programs is strongly recommended in current guidelines for inpatient and outpatient settings.[6–9]

Editorial p????

Despite the proven effectiveness and guideline recommendations of CR for the secondary prevention of cardiovascular diseases, the participation in CR remains low and regional variation exists globally.[10,11] In addition, compared to inpatient CR, referrals for outpatient CR were lower in patients with HF and with coronary artery disease (CAD)

Received February 27, 2022; revised manuscript received April 16, 2022; accepted April 19, 2022; J-STAGE Advance Publication released online May 27, 2022 Time for primary review: 13 days

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ISSN-1346-9843

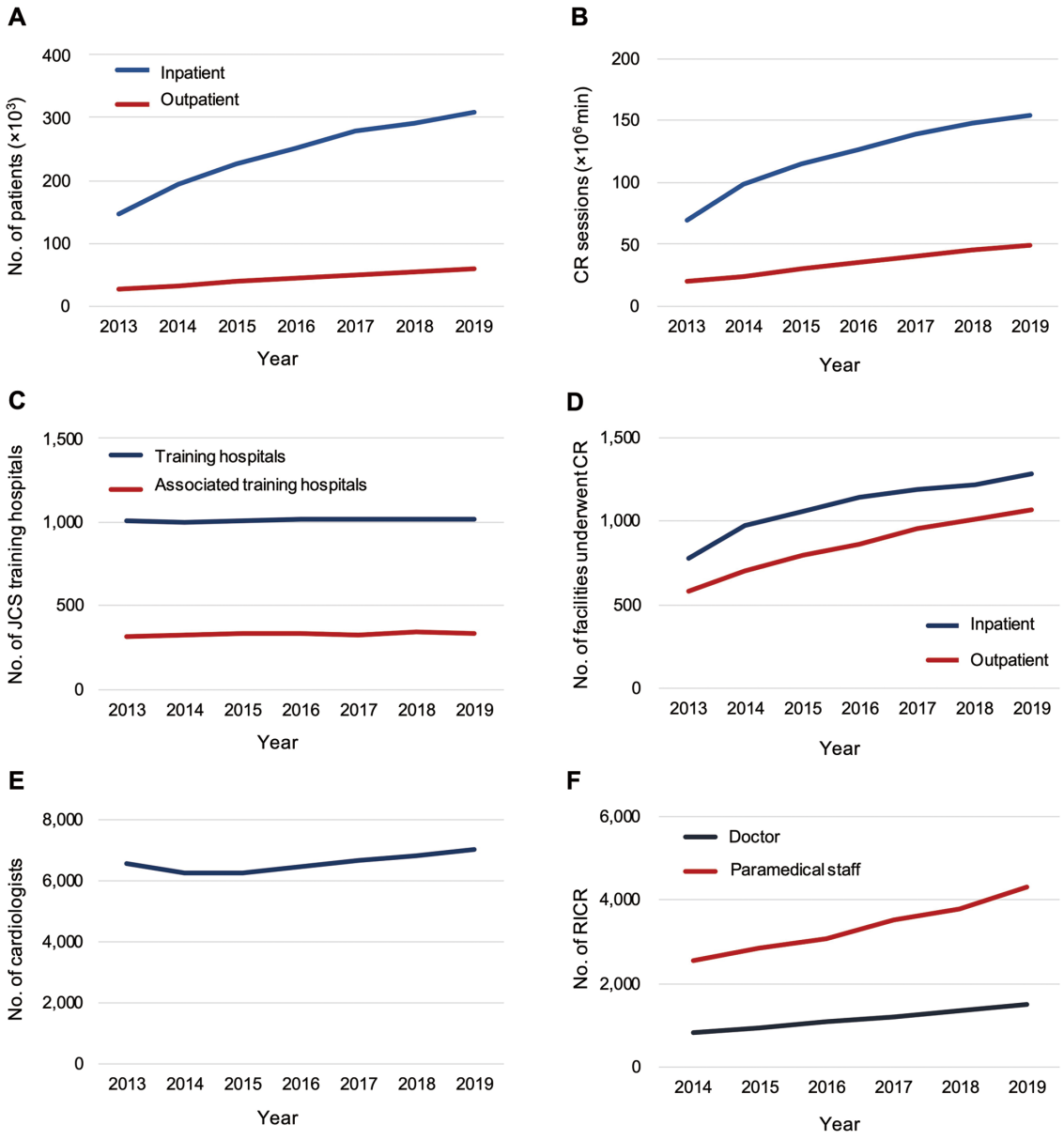

Figure. Trends in cardiac rehabilitation and associated resources for cardiovascular diseases. (**A**) Number of patients who underwent CR (×10³). (**B**) Total time of CR sessions (×10⁶ min). (**C**) Number of JCS training hospitals. (**D**) Number of facilities providing CR. (**E**) Number of JCS-certified cardiologists. (**F**) Number of registered instructor of CR. CR, cardiac rehabilitation; JCS, Japanese Circulation Society.

in the US and particularly in Japan.[12–14] It has been suggested that geographic, institutional, and patient-level factors may contribute to reduced participation in CR, primarily in patients with CAD and HF.[11,15,16] Prior studies have suggested that there is underutilization of CR and patient factors associated with CR participation in patients with myocardial infarction;[15,16] however, few studies have comprehensively evaluated the factors associated with participation in inpatient and outpatient CR across major cardiovascular diseases in a contemporary manner. Therefore, we used the nationwide Japanese databases and clarified the temporal trends and factors associated with participation in CR in inpatient and outpatient settings among patients admitted with major cardiovascular diseases.

Methods

Source of Data

We used two nationwide databases in this study; the National Database of Health Insurance Claims and Specific Health Checkups of Japan (NDB) and the Japanese Registry of All Cardiac and Vascular Diseases and the Diagnosis Procedure Combination (JROAD-DPC) database. The NDB, provided by the Japan Ministry of Health, Labour,

Table 1. Participation in CR According to Major Cardiovascular Diseases

	ACS	AHF	AAD	Surgery	PAD
Inpatient CR*					
Eligible patients (n)	356,507	491,104	84,912	143,546	139,845
Participation rates (n, %)	155,672 (44)	196,776 (40)	42,264 (50)	105,897 (74)	20,129 (14)
First CR date (day)	4 (3–6)	4 (3–8)	5 (3–8)	2 (2–4)†	4 (3–8)
Length of hospital stay (days)	12 (7–18)	18 (12–27)	22 (14–32)	19 (14–27)†	5 (4–12)
Total days of CR during hospitalization (days)	7 (4–10)	9 (5–15)	12 (7–18)	11 (8–17)	6 (2–13)
Outpatient CR					
Eligible patients (n)‡	190,973	205,263	33,090	75,528	92,677
Participation rates (n, %)	15,084 (7.9)	7,102 (3.5)	1,053 (3.2)	7,095 (9.4)	1,534 (1.7)
Total days of CR within 3 months (days)	6 (2–10)	5 (2–10)	4 (2–10)	5 (2–10)	5 (2–10)

Data are presented as n (interquartile range) or n (%) unless otherwise stated. *Patients were included more than once if they fulfilled ≥2 diagnosis criteria of cardiovascular disease. †First CR date and length of hospital stay for patients who underwent cardiac surgery were counted as days after the operation (operation day was calculated as day 1). ‡Patients discharged alive from April to December between 2013 to 2019 and visited the outpatient department of the same hospital within 3 months. AAD, acute aortic diseases; ACS, acute coronary syndrome; AHF, acute heart failure; CR, cardiac rehabilitation; PAD, peripheral artery disease.

and Welfare, is an administrative claims data including almost all of the data on healthcare services provided by healthcare institutions in Japan; therefore, it is used for the nationwide description and prefecture-level analysis for all patients who underwent CR.[17] The JROAD-DPC covers over 900 Japanese Circulation Society (JCS)-certified (associated) training hospitals during the study period and includes detailed patient information such as patients' activities of daily living (ADL) and comorbidities, which were not included in the NDB. Therefore, it was used for patient- and hospital-level analysis of the associated factors for patients with CR who were hospitalized with major cardiovascular diseases.

We used the NDB between April 2013 to March 2020 for this study. The NDB includes claims for both inpatient and outpatient services, anonymized personal identification variables, age groups (5-year groups), sex, codes for medical care received, anonymized facilitation code, and prefectural code.[18] Additionally, we collected the prefectural data regarding the number of Registered Instructors of Cardiac Rehabilitation (RICR), which was provided by the Japanese Association of Cardiac Rehabilitation.

We used the JROAD-DPC between April 2012 to March 2018. The JROAD-DPC is the claim database based on each hospitalization derived from the Japanese DPC/Per Diem Payment System.[19,20] The JROAD-DPC includes patient characteristics such as age, sex, body mass index (BMI), Barthel Index (the performance scale of ADL), Charlson comorbidity index, and diagnostic codes based on the 10th revision of the International Statistical Classification of Diseases (ICD-10) codes and outcome categories. The JROAD-DPC database was merged with the hospital-level database (JROAD), which includes hospital characteristics such as the number of JCS-certified cardiologists in each hospital.[21]

Study Design and Population

This was a cross-sectional study that used the NDB and the JROAD-DPC database. We evaluated the trends and explored the associated factors with the participation of CR patients in both inpatient and outpatient settings.

First, we performed a descriptive study on the nationwide trends of CR and resources associated with CR in both inpatient and outpatient settings. The trends regarding the number of patients aged ≥20 years who underwent CR, the total time of CR sessions (min), the number of facilities providing CR, the number of JCS (associated) training hospitals, the number of JCS-certified cardiologists, and the number of RICR were described. The annual total number of patients and facilities were counted if CR was undertaken ≥1 time per year. In the Japanese health insurance system, every 20 min of CR time is counted as 1 "unit", and the number of units performed in each session is included in the administrative database. The trend of the number of patients who underwent CR was categorized based on age (–64, 65–74, 75– years).

Second, the prefecture-level ecological study of the number of patients who underwent CR for all cardiovascular disease categories and associated factors in all 47 prefectures in Japan was performed. We used the data of the fiscal year 2017, which was the latest year available for the number of JCS training hospitals and cardiologists in the JROAD. We analyzed the prefecture-level correlation between the number of CR sessions and prefecture-level factors.

Finally, we performed the patient-level analysis of the associated factors with CR participation using JROAD-DPC between April 2012 to March 2018. We extracted data for patients who were hospitalized with major acute cardiovascular diseases, including ACS, acute HF, acute aortic disease (AAD), post-open surgery for cardiovascular diseases, and lower extremity peripheral artery disease (PAD) and those who underwent endovascular therapy or bypass surgery. The definitions of diagnosis were based on the ICD-10 codes or procedural codes as follows: I200, I21, I22, I23, and I249 with emergency hospitalization for ACS; I50, I110, I130, I132 with emergency hospitalization and additional disease codes of acute HF or acute decompensation of chronic HF for acute HF; I71 with emergency hospitalization for AAD; the procedural codes for open surgery with K539-2, K540, K544, K551, K552, K552-2, K553, K553-2, K554, K554-2, K555, K555-2, K555-3, K556, K557, K557-2, K557-3, K557-4, K558, K559, K560, K560-2, K577, K592, K592-2, K593; I702 and I743 with the procedural codes for endovascular therapy or bypass for PAD. The positive predictive values of ACS and AHF using our criteria were 84.9% and 83.0% in the prior validation study.[22] Patients aged <20 years and with a duration

Table 2. Patient and Hospital Characteristics Associated With Inpatient CR Participation

	ACS			AHF			AAD		
	OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Age (years)									
<65	Ref.			Ref.			Ref.		
65–74	0.88	0.86–0.90	<0.01	1.20	1.16–1.24	<0.01	0.96	0.91–1.01	0.09
≥75	0.81	0.79–0.83	<0.01	1.54	1.50–1.59	<0.01	0.80	0.77–0.84	<0.01
Female	0.86	0.84–0.88	<0.01	1.08	1.06–1.09	<0.01	1.28	1.23–1.33	<0.01
BMI, kg/m²									
<18.5	Ref.			Ref.			Ref.		
18.5–24.9	1.19	1.14–1.23	<0.01	1.08	1.06–1.11	<0.01	1.19	1.13–1.26	<0.01
25.0–29.9	1.19	1.14–1.23	<0.01	1.10	1.07–1.13	<0.01	1.33	1.25–1.42	<0.01
≥30	1.09	1.04–1.15	<0.01	1.27	1.22–1.32	<0.01	1.39	1.26–1.53	<0.01
Barthel index on admission									
≤90	Ref.			Ref.			Ref.		
>90	0.70	0.68–0.71	<0.01	0.79	0.77–0.80	<0.01	1.00	0.95–1.07	0.88
Missing	2.08	2.03–2.13	<0.01	0.95	0.93–0.97	<0.01	1.55	1.46–1.63	<0.01
Charlson score									
≤1	Ref.			Ref.			Ref.		
2	2.26	2.21–2.31	<0.01	1.04	1.02–1.06	<0.01	1.13	1.08–1.18	<0.01
≥3	2.26	2.21–2.32	<0.01	0.88	0.87–0.90	<0.01	1.05	1.01–1.11	0.03
No. of cardiologists									
≤4	Ref.			Ref.			Ref.		
5–8	1.16	1.12–1.22	<0.01	1.23	1.19–1.28	<0.01	1.41	1.30–1.53	<0.01
≥9	1.28	1.20–1.36	<0.01	1.63	1.53–1.73	<0.01	1.63	1.45–1.83	<0.01
No. of hospitalized patients									
<1,000	Ref.			Ref.			Ref.		
1,000–1,999	1.16	1.10–1.22	<0.01	1.28	1.22–1.34	<0.01	1.48	1.32–1.65	<0.01
≥2,000	1.12	1.04–1.20	<0.01	1.47	1.38–1.57	<0.01	1.59	1.38–1.83	<0.01
Seven regions in Japan									
Hokkaido and Tohoku	Ref.			Ref.			Ref.		
Kanto	0.96	0.70–1.32	0.79	0.81	0.56–1.16	0.25	1.23	0.86–1.73	0.28
Cyubu	0.87	0.62–1.21	0.42	0.72	0.49–1.05	0.09	0.75	0.52–1.08	0.12
Kinki	1.00	0.72–1.39	0.99	0.97	0.67–1.40	0.87	0.72	0.50–1.03	0.07
Chugoku	1.06	0.69–1.62	0.80	1.00	0.61–1.62	0.98	0.97	0.61–1.54	0.89
Shikoku	1.21	0.73–2.01	0.46	1.14	0.64–2.03	0.66	0.97	0.55–1.71	0.93
Kyushu	1.50	1.07–2.10	0.02	1.85	1.26–2.70	<0.01	1.31	0.91–1.90	0.15

BMI, body mass index; CI, confidence interval; OR, odds ratio. Other abbreviations as in Table 1.

(**Table 2** continued the next page.)

of hospital stay ≤2 days were excluded. We described the proportion of the patient participation in CR and the total days of CR in inpatient and outpatient settings by disease category. Subsequently, we evaluated the association between CR participation and the patient- and hospital-level characteristics in inpatient and outpatient settings. Patients hospitalized in facilities without the certification of the CR program (i.e., they did not meet the criteria for the number of staff and equipment) and those with missing variables were excluded. In the outpatient CR analysis, the patients discharged alive and who attended as outpatients at the same hospital were included because the JROAD-DPC database does not include the follow-up data of the same patients transferred to another hospital.

Statistical Analysis

Patient clinical characteristics are described as numbers and percentages for categorical variables or median and interquartile range (IQR) for continuous variables.

In the prefecture-level analysis, we examined the correlations of the number of patients in both inpatient and outpatient CR. The correlations between the number of patients who underwent inpatient/outpatient CR and the prefecture-level factors were analyzed using Pearson's linear correlation coefficient.[23]

In the patient-level descriptive analysis, mixed-effect logistic regression analysis, using the institution as a random intercept, was performed to examine the association between the inpatient and outpatient CR participation and each variable. Candidate predictors included patient-level factors (age, sex, body mass index, Barthel index, and Charlson score), facility-level factors (the number of JCS-certified cardiologists and the total number of hospitalized patients per year), and seven regions in Japan. The cut-off value of body mass index and the Barthel index was determined by prior studies.[24,25] The number of cardiologists and the number of hospitalized patients were divided into 3 groups: ≤4, 5–8, and ≥9 for the number of

	Surgery			PAD		
	OR	95% CI	P value	OR	95% CI	P value
Age (years)						
<65	Ref.			Ref.		
65–74	1.20	1.14–1.27	<0.01	1.07	1.01–1.13	0.03
≥75	1.25	1.18–1.32	<0.01	1.27	1.20–1.34	<0.01
Female	0.97	0.92–1.01	0.13	1.02	0.98–1.06	0.28
BMI, kg/m²						
<18.5	Ref.			Ref.		
18.5–24.9	1.11	1.04–1.19	<0.01	0.89	0.85–0.94	<0.01
25.0–29.9	1.20	1.11–1.29	<0.01	0.80	0.75–0.86	<0.01
≥30	1.36	1.20–1.53	<0.01	0.94	0.84–1.06	0.34
Barthel index on admission						
≤90	Ref.			Ref.		
>90	1.08	1.01–1.16	0.03	0.42	0.40–0.44	0.04
Missing	0.80	0.73–0.87	<0.01	1.39	1.31–1.48	<0.01
Charlson score						
≤1	Ref.			Ref.		
2	1.08	1.03–1.13	<0.01	1.05	1.00–1.11	0.04
≥3	1.09	1.03–1.15	<0.01	0.92	0.88–0.96	<0.01
No. of cardiologists						
≤4	Ref.			Ref.		
5–8	1.37	1.23–1.53	<0.01	1.09	1.00–1.18	0.04
≥9	2.97	2.56–3.45	<0.01	1.10	0.98–1.24	0.11
No. of hospitalized patients						
<1,000	Ref.			Ref.		
1,000–1,999	1.59	1.37–1.84	<0.01	1.39	1.24–1.55	<0.01
≥2,000	1.63	1.36–1.96	<0.01	1.39	1.20–1.61	<0.01
Seven regions in Japan						
Hokkaido and Tohoku	Ref.			Ref.		
Kanto	0.77	0.38–1.60	0.49	0.52	0.35–0.76	<0.01
Cyubu	0.44	0.20–0.98	0.04	0.56	0.37–0.83	<0.01
Kinki	0.68	0.31–1.46	0.32	0.52	0.36–0.77	<0.01
Chugoku	1.19	0.44–3.21	0.73	0.82	0.49–1.37	0.45
Shikoku	0.37	0.11–1.26	0.11	0.62	0.34–1.13	0.12
Kyushu	1.52	0.66–3.54	0.33	1.12	0.75–1.69	0.58

cardiologists and <1,000, 1,000–1,999, ≥2,000 for the number of hospitalized patients. The Barthel index was one of the crucial factors for the selection of CR; however, the proportion of the missing variables was high, particularly on admission. We, therefore, added the Barthel index to the model with missing variables and performed a complete case analysis for other variables. The total score of the Barthel index was regarded as having missing variables if even one missing value existed in each item. The patient- and facility-level non-normally distributed factors were analyzed as categorical variables. A 2-sided P value of <0.05 was considered statistically significant. The data analysis was performed using Stata 16 (Stata Corp., College Station, TX, USA).

Ethics Statement

The study protocol for the NDB was approved by the ethics committees of the Japanese Red Cross Toyota College of Nursing (registration number: 2006). This study was conducted in accordance with the principles of the Declaration of Helsinki. The requirement for individual informed consent was waived because all data were anonymized when provided.

Results

Trends in CR Participation and Associated Resources

For the study period from 2013 to 2019, the annual number of patients who underwent CR increased in both inpatient (2.1-fold increase) and outpatient (2.2-fold increase) settings. The annual total time of CR sessions also increased in both inpatient (2.2-fold increase) and outpatient (2.4-fold increase) settings (**Figure A**,**B**). However, the annual number of patients and the total number of sessions for outpatient CR were low (approximately 310×10^3 patients and 16×10^6 min in 2019) compared to those for inpatient CR (approximately 58×10^3 patients and 4.8×10^6 min in 2019).

Although the number of JCS-certified training facilities and the number of JCS-certified cardiologists were almost unchanged during the study period, the annual number of facilities that provided CR (1.6-fold increase in inpatient

Table 3. Patient and Hospital Characteristics Associated With Outpatient CR Participation

	ACS			AHF			AAD		
	OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Age (years)									
<65	Ref.			Ref.			Ref.		
65–74	0.90	0.86–0.94	<0.01	0.85	0.80–0.90	<0.01	0.77	0.67–0.89	<0.01
≥75	0.50	0.48–0.52	<0.01	0.41	0.38–0.43	<0.01	0.39	0.34–0.46	<0.01
Female	0.85	0.81–0.89	<0.01	0.81	0.78–0.86	<0.01	1.35	1.19–1.53	<0.01
BMI, kg/m²									
<18.5	Ref.			Ref.			Ref.		
18.5–24.9	1.52	1.38–1.66	<0.01	1.28	1.18–1.39	<0.01	1.96	1.50–2.56	<0.01
25.0–29.9	1.56	1.42–1.72	<0.01	1.34	1.23–1.47	<0.01	2.14	1.61–2.85	<0.01
≥30	1.56	1.39–1.74	<0.01	1.57	1.41–1.74	<0.01	2.32	1.65–3.27	<0.01
Barthel index at discharge									
≤90	Ref.			Ref.			Ref.		
>90	2.64	2.41–2.89	<0.01	2.87	2.66–3.09	<0.01	1.92	1.48–2.47	<0.01
Missing	1.63	1.43–1.85	<0.01	1.14	1.02–1.30	0.04	1.36	0.94–1.97	0.11
Charlson score									
≤1	Ref.		<0.01	Ref.			Ref.		
2	1.59	1.52–1.65	<0.01	1.03	0.97–1.08	0.38	1.04	0.91–1.19	0.60
≥3	1.30	1.24–1.36	<0.01	0.79	0.75–0.83	<0.01	0.85	0.72–1.01	0.07
No. of cardiologists									
≤4	Ref.			Ref.			Ref.		
5–8	1.50	1.38–1.63	<0.01	1.34	1.22–1.49	<0.01	1.66	1.25–2.19	<0.01
≥9	1.16	1.02–1.33	0.03	1.71	1.44–2.02	<0.01	1.76	1.21–2.58	<0.01
No. of hospitalized patients									
<1,000	Ref.			Ref.			Ref.		
1,000–1,999	1.01	0.92–1.12	0.78	1.15	1.01–1.30	0.03	0.74	0.54–1.01	0.06
≥2,000	1.14	1.00–1.30	0.05	1.25	1.05–1.48	0.01	0.73	0.49–1.08	0.12
Seven regions in Japan									
Hokkaido and Tohoku	Ref.			Ref.			Ref.		
Kanto	1.27	0.66–2.43	0.48	0.80	0.45–1.41	0.44	2.60	1.27–5.32	0.01
Cyubu	1.99	1.01–3.94	0.05	1.22	0.67–2.20	0.52	1.25	0.58–2.70	0.57
Kinki	3.72	1.91–7.25	<0.01	2.38	1.34–4.23	<0.01	2.67	1.27–5.62	0.01
Chugoku	1.73	0.72–4.15	0.22	1.13	0.53–2.40	0.75	0.71	0.25–2.04	0.53
Shikoku	1.37	0.50–3.78	0.54	0.93	0.38–2.27	0.87	0.36	0.08–1.66	0.19
Kyushu	0.97	0.50–2.00	0.99	1.20	0.66–2.17	0.56	2.14	0.97–4.70	0.06

Abbreviations as in Tables 1,2.

(**Table 3** continued the next page.)

and 1.8-fold increase in outpatient settings) and the total number of RICR (1.8-fold increase in the number of doctors and 1.7-fold increase in the number of paramedical staff from 2014 to 2019) has increased (**Figure C–F**).

CR Trends by Age Categories

The proportion of patients aged ≥75 years who underwent CR was higher in inpatient CR than in outpatient CR settings throughout all years (**Supplementary Figure 1A,B**). The annual number of patients aged ≥75 years who underwent inpatient CR was greater (2.5-fold increase) compared with the annual number of patients aged <75 years (1.6-fold and 1.7-fold increase in patients aged 20–64 and 65–74 years, respectively) (**Supplementary Figure 1A**). The annual number of patients aged ≥75 years who underwent outpatient CR also increased (2.9-fold increase) compared with the annual number of patients aged <75 years (1.8-fold increase in patients aged 20–64 years and 1.9-fold increase in patients aged 65–74 years) (**Supplementary Figure 1B**).

Prefecture-Level Factors Associated With the Number of Patients Who Underwent CR

The correlation between the number of patients who underwent CR and each factor at the prefecture-level is shown in **Supplementary Figure 2**. The number of facilities that provided inpatient CR (r=0.69), the number of JCS-certified cardiologists (r=0.50), and the number of RICR (doctor [r=0.52] and paramedical staff [r=0.59]) showed moderate correlation with the number of patients who underwent inpatient CR. In the outpatient setting, the number of facilities that provided outpatient CR (r=0.42) and the number of JCS-certified cardiologists (r=0.40) showed a moderate correlation with the number of patients who underwent CR.

Current Status of CR Across Major Cardiovascular Diseases

A total of 356,507 patients with ACS, 491,104 patients with acute HF, 84,912 patients with AAD, 143,546 patients who underwent open surgery, and 139,845 patients with PAD

	Surgery			PAD		
	OR	95% CI	P value	OR	95% CI	P value
Age (years)						
<65	Ref.			Ref.		
65–74	0.85	0.80–0.91	<0.01	1.26	1.09–1.44	<0.01
≥75	0.62	0.58–0.67	<0.01	1.00	0.87–1.15	0.99
Female	0.89	0.84–0.94	<0.01	0.98	0.88–1.10	0.71
BMI, kg/m²						
<18.5	Ref.			Ref.		
18.5–24.9	1.17	1.06–1.30	<0.01	1.28	1.08–1.52	<0.01
25.0–29.9	1.25	1.13–1.39	<0.01	1.42	1.17–1.72	<0.01
≥30	1.24	1.07–1.45	0.01	1.72	1.27–2.33	<0.01
Barthel index at discharge						
≤90	Ref.			Ref.		
>90	2.18	1.91–2.50	<0.01	2.36	1.95–2.85	<0.01
Missing	1.50	1.23–1.83	<0.01	0.98	0.69–1.38	0.90
Charlson score						
≤1	Ref.			Ref.		
2	0.98	0.92–1.04	0.51	1.14	1.00–1.30	0.04
≥3	0.75	0.70–0.80	<0.01	1.04	0.92–1.17	0.51
No. of cardiologists						
≤4	Ref.			Ref.		
5–8	1.72	1.51–1.96	<0.01	1.11	0.92–1.35	0.28
≥9	1.85	1.57–2.19	<0.01	1.23	0.92–1.64	0.17
No. of hospitalized patients						
<1,000	Ref.			Ref.		
1,000–1,999	1.00	0.84–1.20	0.99	0.74	0.58–0.94	0.01
≥2,000	0.98	0.78–1.21	0.89	0.86	0.61–1.20	0.36
Seven regions in Japan						
Hokkaido and Tohoku	Ref.			Ref.		
Kanto	2.71	1.25–5.89	0.01	1.17	0.59–2.33	0.65
Cyubu	1.54	0.66–3.58	0.32	1.55	0.76–3.19	0.23
Kinki	3.12	1.37–7.11	0.01	2.01	1.02–4.00	0.04
Chugoku	0.86	0.29–2.52	0.78	1.02	0.40–2.61	0.97
Shikoku	0.29	0.07–1.21	0.09	0.79	0.26–2.36	0.67
Kyushu	0.80	0.32–2.00	0.64	1.01	0.48–2.15	0.97

were included in the description study (**Supplementary Figure 3**). The proportion of inpatient CR participation was 44% (N=155,672) for ACS, 41% (N=196,776) for acute HF, 50% (N=42,264) for AAD, 74% (N=105,897) for post-open surgery, and 14% (N=20,129) for PAD (**Table 1**). The proportion of outpatient CR participation was lower than that of inpatient CR participation; 7.9% in ACS, 3.5% in AHF, 3.2% in AAD, 9.4% for post-open surgery, and 1.7% for PAD.

Factors Associated With CR Participation Across Cardiovascular Diseases

After removing patients hospitalized in non-certified CR hospitals and patients with missing variables, a total of 259,658 patients with ACS, 333,947 patients with acute HF, 64,372 patients with AAD, 123,312 patients with post-open surgery, and 110,727 patients with PAD were included in the analysis for the association between CR participation and clinical factors (**Supplementary Figure 3**). The median (IQR) age and the proportion of females were 71 (62–79) years and 27% (N=71,396) for patients with ACS, 82 (73–87) years and 47% (N=157,291) for patients with acute HF, 74 (65–82) years and 37% (N=23,922) for patients with AAD, 72 (64–78) years and 36% (N=44,463) for patients with post-open surgery, and 74 (67–80) years and 17% (N=19,301) for patients with PAD (**Supplementary Table**).

For inpatient CR, the CR participation rates were lower in older patients with ACS and AAD, but were higher in older patients with acute HF, post-open surgery, and PAD (**Table 2**). Female patients with ACS were less likely to undergo CR, whereas female patients with acute HF, AAD, and PAD were more likely to undergo CR. Patients with a body mass index ≥18.5 kg/m² and a Charlson score ≥2 were associated with higher participation in CR. Patients with ACS, acute HF, and PAD with a higher Barthel index (≥90) were less likely to undergo CR. A greater number of JCS-certified cardiologists and hospitalized patients in the cardiovascular department were associated with a higher participation rate in inpatient CR.

Compared to inpatient CR, older age was associated with a lower outpatient CR participation rate in most of

the disease groups (**Table 3**). Female patients were less likely to participate in outpatient CR, as were patients with ACS, acute HF, and post-open surgery. Contrary to inpatient CR, a higher Barthel index (≥90) was associated with the higher participation rate of outpatient CR. A higher number of JCS-certified cardiologists at the admitting hospital was associated with a higher participation rate of patients in outpatient CR.

Discussion

In the nationwide databases in Japan, we identified the following findings: (1) inpatient and outpatient CR had increasing trends from 2013 to 2019; (2) the outpatient CR participation rate was lower than the inpatient CR; and (3) both the patient-level factors (age, sex, body mass index, Barthel index, Charlson comorbidity index) and institutional-level factors (the number of cardiologists and the number of hospitalized patients) were associated with the CR participation, and the effect of some of the associated factors differed by CR settings and cardiovascular diseases.

Few large-scale studies have evaluated the factors associated with CR participation in patients with major cardiovascular diseases. To our knowledge, this is the first study to comprehensively evaluate the factors associated with the participation in inpatient and outpatient CR using nationwide real-world databases in Japan. By addressing the gap in knowledge about CR participation, the present study findings on the clinical factors associated with CR participation in patients with major cardiovascular diseases could support targeted interventions to improve CR attendance and, potentially, improve patients' outcomes.

Lower Outpatient CR Participation

Although the number of patients who underwent CR, the total number of CR sessions, and the number of facilities providing CR increased from 2013 to 2017, the participation rate for outpatient CR was lower than that of inpatient CR. The lower participation in outpatient CR was consistent with the findings of another study in Japan;[26] however, the prior study did not suggest methods to address this.

Our study included information on how to increase CR participation based on the patient-level association analysis and the prefecture-level correlation analysis. The patient-level association analysis revealed that the older patients with lower ADL were likely to undergo inpatient CR, but less likely to undergo outpatient CR. Therefore, we need to consider ways to increase outpatient CR for older and more frail patients with cardiovascular diseases. In the prefecture-level correlation analysis, the number of facilities per population exhibited a moderate positive correlation with the number of patients participating in outpatient CR. One of the key factors to increase outpatient CR participation is access to CR facilities. To increase the number of patients attending outpatient CR, we need to increase the number of facilities available for outpatient CR in the few medical resource areas for both hospitals and clinics.

Inpatient and Outpatient CR Participation for Each Disease

The proportion of patients attending inpatient CR was higher for patients who have had surgery compared with patients who have other cardiovascular diseases; additionally, most of the patients underwent early rehabilitation after surgery. The higher participation rate in CR for patients who are post-cardiovascular surgery was consistent with the results found in a prior study.[27] Contrary to the patients with ACS, acute HF, and AAD who required emergency hospitalization, where CR initiation was determined by cardiologists, patients who underwent surgery had a higher proportion of planned hospitalizations, which may lead to scheduled participation and a high participation rate in inpatient CR after surgery.

The outpatient CR participation rate was lower in patients with acute HF, AAD, and PAD compared to patients with ACS and patients who underwent post-open surgery. The low participation rate in outpatient CR for patients with HF was demonstrated by another study using a questionnaire in Japan.[28] The present study suggests that the lower outpatient CR participation rate might be because of the higher proportion of older patients with acute HF and AAD compared to patients with ACS and those who underwent post-open surgery.

Barriers to CR Participation and Future Perspectives

Our study demonstrated marked differences in factors associated with CR participation between inpatients and outpatients. We revealed that older age, being female, having a lower BMI, and a lower ADL at discharge were associated with decreased participation rate in outpatient CR. These results were consistent with those of a recent study describing the underuse of CR among older female patients after myocardial infarction.[16,29,30] Hence, this population should be specifically targeted to improve CR participation. Additionally, our study revealed that facility-level factors such as the number of cardiologists and the number of hospitalized patients were associated with higher CR participation rates in inpatient and outpatient settings, implying that the large centralized hospitals are more actively introducing both inpatient and outpatient CR.

Outpatient CR is mainly provided to a limited number of patients in hospitals with abundant medical resources in Japan, and new strategies are needed to increase outpatient CR participation. In contrast to hospital-based CR, home-based CR or remote CR may be a reasonable strategy for increasing the participation rate of outpatient CR.[31] Providing useful options to the population who are older, frail, and with multi-comorbidity will help increase the participation rate of outpatient CR in future.

Study Limitations

Although this was a nationwide cross-sectional study that included most of the Japanese population, this study has some limitations. First, the NDB and the JROAD-DPC did not include detailed patients' characteristics, such as laboratory and physiological data and educational and economic status; therefore, there could be other factors associated with CR participation. Second, the database did not include the contents of the CR program, such as exercise intensity and components, and we could not evaluate the quality of the CR program according to patient characteristics and disease category. Third, although the accuracy of ICD-10 for ACS and acute HF is well-validated, the accuracy of AAD diagnosis is still not validated. Finally, the JROAD-DPC is not available for all rehospitalization data, such as readmissions for other hospitals. so we analyzed the data based on the hospitalization, and not on the patient.

Conclusions

This study revealed an increasing trend of CR participation in both inpatient and outpatient with cardiovascular diseases in Japan; however, the participation rate in outpatient CR was low across all cardiovascular groups. Age, sex, body mass index, Barthel index, comorbidities, and institutional capacity were identified as associated factors of CR participation, which could aid cardiologists in improving CR participation after hospitalization with major cardiovascular diseases. More aggressive efforts are required to increase CR participation by considering the trend and predictors.

Acknowledgments

We are grateful to Mr. Tsuneyuki Higashino and all investigators at Mitsubishi Research Institute Inc., Tokyo, Japan, for data preparation and management.

Sources of Funding

This work was supported by a grant from the Labor Research Grant (Grant Number: 19FA1002 and 21FA1012) from the Ministry of Health, Labour and Welfare, Japan.

Disclosures

Y. Sakata is a member of *Circulation Journal*'s Editorial Team. All other authors have no conflicts of interest to declare.

Author Contributions

K.K. and N.F. conceived the study. T.I. obtained research funding. K.K., Y.I., M.N., Y. Sumita, Y.N., T.N., and T.I. managed the data. M.N., K.O., Y. Sakata, and Y.M. provided statistical advice on the study design and analysis. K.K. drafted the manuscript, and all authors contributed substantially to its revision. All authors agree with the content of the manuscript.

IRB Information

The ethics committees of the Japanese Red Cross Toyota College of Nursing (registration number: 2006) approved this study.

Data Availability

Deidentified participant data will not be shared.

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Supplementary Files

Please find supplementary file(s);
http://dx.doi.org/10.1253/circj.CJ-22-0095