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Participation and Prognostic Impact of Cardiac Rehabilitation After Acute Coronary Syndrome: Big-Data Study of the Korean National Health Insurance Service

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ABSTRACT

Background: To investigate the actual rate and quality of cardiac rehabilitation (CR) participation in South Korea and its short-term impact on clinical outcomes after acute coronary syndrome (ACS).
Methods: Data, including confirmed ACS diagnosis, socio-demographics, comorbidities, clinical outcomes, and CR claim codes, were collected from the Korean National Health Insurance Service claims database and compared between the CR and non-CR groups.
Results: Overall, 102,544 patients were included in the study, of which only 5.8% attended CR. Regarding testing, 83.6% of CR patients performed the cardiopulmonary exercise test, but follow-up testing was infrequently performed; in addition, 53.1% of them participated in an electrocardiogram monitoring exercise, but over half participated in only one session. After 1:1 propensity score matching, post-ACS cardiovascular events were significantly lower in the CR group than in the non-CR group. The cumulative 3-year hazard ratio for all-cause death was 0.612 (95% confidence interval [CI], 0.495–0.756), recurrent ACS was 0.92 (95% CI, 0.853–0.993), CR readmission was 0.817 (95% CI, 0.768–0.868), and major adverse cardiovascular events (MACE) was 0.827 (95% CI, 0.781–0.874) in the CR group. CR was associated with a significant dose-response effect on MACE, with a reduction in incidence from 0.854 to 0.711.
Conclusion: The actual rate of CR participation in South Korea remains low, and participation quality was not outstanding despite National Health Insurance coverage. Nevertheless, the impact of CR on cardiovascular outcomes after ACS was significantly superior. Efforts to increase CR participation should be increased by establishing new CR facilities and strategies to resolve associated barriers.

Keywords: Acute Coronary Syndrome; Cardiac Rehabilitation; Korean Health Insurance Data

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Disclosures

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Choi HE, Kim C. Data curation: Choi HE, Joo JE, Kim HS. Formal analysis: Choi HE, Joo JE, Kim HS. Funding acquisition: Choi HE. Investigation: Choi HE, Joo JE, Kim HS. Methodology: Choi HE, Kim C. Project administration: Choi HE. Software: Lee DJ. Supervision: Choi HE, Kim C. Validation: Choi HE, Kim C. Visualization: Choi HE, Kim C, Joo JE, Kim HS. Writing - original draft: Kim C, Choi HE. Writing - review & editing: Choi HE, Kim C, Lee DJ.

INTRODUCTION

Heart disease is the leading cause of death worldwide and responsible for an estimated 16% of the total global mortality.[1] Although the total mortality rate of cardiovascular disease (CVD) in South Korea has significantly decreased, heart disease remains the second leading cause of death, and ischemic heart disease (IHD) mortality has continuously increased until recently.[2,3] The increase in CVD burden is most likely due to the aging of the global population, accompanied by an increase in the prevalence of modifiable risk factors.[3,4]

Although most cases of CVD manifest clinically as an acute disease, they are actually chronic degenerative diseases that progress over time.[5] Therefore, patients with CVD should receive cardiac rehabilitation (CR) after hospital discharge; however, the actual CR participation rate is approximately 20–40% even among countries with advanced medical care.[6]

A comprehensive CR program was introduced in South Korea in the late 1990s, and there has been a subsequent increase in CR participation. However, hospital-based CR has not been actively applied to eligible patients, and one report from 2017 showed that the CR participation rate among 26 CR-providing facilities was approximately only 1.5%.[7] Currently, 47 (28.7%) of 164 hospitals that practice percutaneous coronary intervention (PCI) have CR programs; therefore, the number of CR facilities remains insufficient, and there are regional gaps when considering the number of IHD cases in South Korea.[8] Furthermore, participation in CR remains consistently poor, except in several unique CR-specialized hospitals.

The purpose of this study was to investigate the actual nationwide practice rate of CR and its impact on clinical outcomes after acute coronary syndrome (ACS) using the medical claims data of the National Health Insurance Service (NHIS).[9] To our knowledge, this is the first study to reveal the impact of CR on clinical outcomes after ACS and the dose-response relationship between the numbers of CR sessions attended and the risk of death and recurrence using a cohort of NHIS insurance claim data. This study demonstrates the actual status of CR in South Korea in terms of CR participation and adherence, possible regional and institutional gaps, and the number of CR sessions attended to date.

METHODS

Data sources

Data for this study were obtained from the NHIS database of South Korea. As a single-payer healthcare system, the NHIS provides obligatory health insurance for all residents of Korea, covering more than 97% of the country's population (approximately 51 million people).[10] In addition, the NHIS also operates the National Health Insurance Sharing Service to support policy and academic research using public health information.[11] The NHIS database is a public database comprising patients' socio-demographic data; medical claim codes; diagnoses confirmed by the International Classification of Diseases, 10th revision, Clinical Modification codes; and date of death.[12] Access to the research data was approved by the Review Committee of the National Health Research Institutes.

Selection of participants

This nationwide retrospective cohort study was based on Korean NHIS (KNHIS) data recorded from January 1, 2017 to December 31, 2019. Inclusion criteria were as follows: all patients who were hospitalized for acute myocardial infarction (AMI) (I21, I22, I23, I25.2, and I25.5) or unstable angina (UA) (I20 and I24) and who underwent PCI or coronary artery bypass graft (CABG) surgery defined by the presence of one of the following claim codes: PCI (M6551, M6552, M6561, M6562, M6563, M6564, M6571, and M6572), CABG (O1641, O1642, O1647, OA641, OA642, OA647, O0161, O0170, and O0171), or thrombolysis (M6533 and M6534) during the index admission from January 1, 2017 to December 31, 2018. Exclusion criteria were any pre-existing conditions of AMI or UA from 2014 to 2016.

Measurement

CR attendance was defined by the presence of at least one claim code for MM451 (CR education), MM452 (CR evaluation), or MM453 (CR therapy), regardless of in- or outpatient status. To evaluate compliance to the CR program, data regarding CR attendance, grading of hospitals where CR was performed, and the frequency of each claim code were collected to assess CR education, CR evaluation (cardiopulmonary exercise [CPX] test), and CR therapy (monitoring exercise). We compared demographic data, diagnosis, type of intervention, and comorbidities between the CR and non-CR groups.

Cardiovascular outcomes

To compare the impact of CR on clinical outcomes after ACS, we checked the cardiovascular outcomes during the follow-up periods after index admission by using request data. Cardiovascular outcomes included all-cause death, recurred ACS, revascularization, cardiovascular readmission, and major adverse cardiovascular events (MACE) based on CR attendance. All-cause death was defined as death from any cause until December 31, 2019. ACS recurrence, revascularization, and cardiovascular readmission were defined as in **Table 1**,[13] during the follow-up period, using the claim codes. MACE was defined as the composite of all-cause death, ACS recurrence, revascularization, and cardiovascular readmission. All cardiovascular outcome indices were obtained from the NHIS database using each claim code.

Statistical analysis

A 1:1 propensity score (PS) matched analysis was conducted to minimize differences between the CR and non-CR groups using socio-demographic data (sex and age), diagnosis (disease code), comorbidities (hypertension, diabetes mellitus, dyslipidemia, chronic kidney disease,

Table 1. Definition of clinical events

CV events	Definition
All-cause death	• If there is a medical result classification code (death) after 90 days from discharge, or in case the main diagnosis or 1st sub diagnosis is R96, R98, R99
Recurrence of ACS	• MI: if there is a hospitalization history of main diagnosis or 1st sub diagnosis with code I21, I22, I23, I25.2, I25.5 + a record of emergency medical management fee code[a] • Unstable angina: if there is a main diagnosis or 1st sub diagnosis with code I20.0, I24 + if the patient received PCI or CABG during hospitalization • Stent thrombosis: if there is code T82 (complications of cardiac and vascular prosthetic devices, implants and grafts) after undergoing PCI • Patient with history of MI, unstable angina, or stent thrombosis and who received cardiac enzyme test[b]
Revascularization	• If the patient underwent another PCI or CABG after 90 days from discharge of first PCI or CABG
CV readmission	• Hospitalization for cardiovascular disease: if hospitalized for more than 2 days after 90 days from discharge due to MI, unstable angina, cerebrovascular disease[c], stent thrombosis, reperfusion, etc. • Other hospitalization: hospitalization for more than 2 days after 90 days from discharge
MACE	• If the following event occurred, considering the number of cases, at least once in the order of all-cause death, revascularization, relapse, and readmission for cardiovascular disease

CV = cardiovascular, ACS = acute coronary syndrome, MACE = major adverse cardiovascular events, MI = myocardial infarction regardless of ST-elevation myocardial infarction or non-ST-elevation myocardial infarction, PCI = percutaneous coronary intervention, CABG = coronary artery bypass graft.
[a]Emergency medical management fee (AC101, AC103, AC105, V1100, V1200, V1300, V1400) or department of emergency medicine.
[b]Troponin-T (C3941), troponin I (C3942), creatine kinase-MB (B2640).
[c]Hospitalization with I60–I69 without history of cerebrovascular disease.

cerebrovascular disease, cancer, and chronic obstructive pulmonary disease), and type of insurance. The balance of the study population's characteristics was evaluated utilizing the absolute standardized difference. Baseline characteristics were summarized using descriptive statistics and presented as frequencies and percentages of patients or means with standard deviation. Kaplan-Meier survival curves and log-rank tests were utilized to compare the cumulative incidence rates of cardiovascular outcomes according to CR attendance. In addition, Cox proportional hazards regression analysis was used to estimate the hazard ratio (HR) of each cardiovascular outcome. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). *P* values of < 0.05 were considered statistically significant.

Ethics statement

Before the data were provided, the NHIS removed confidential and identifying information of all patients to protect their privacy. Therefore, this study was exempt from acquiring patients' informed consent due to the de-identification of all personal information. The study protocol was approved by the Institutional Review Board (IRB) of the Inje University Haeundae Paik Hospital (IRB No. HPIRB 2019-05-028-003), and official approval was obtained from review and assessment committee of the National Health Insurance Servic (No. NHIS-2021-1-129). The data that support the findings of this study were available from the corresponding author upon reasonable request. The data are not publicly available due to privacy or ethical restrictions.

RESULTS

Characteristics of study participants

During the survey, a total of 163,581 patients were identified as potential study candidates; after excluding 61,337 patients based on the selection criteria, 102,544 patients were selected for the study. **Fig. 1** depicts a flowchart illustrating the number of patients who met the inclusion criteria, the number of excluded patients, and the reasons for their exclusion. The patient characteristics are shown in **Table 2**. The standardized mean difference values of all characteristic variables were less than 0.1, indicating that there was no significant difference in patient characteristics between the two groups. In the original cohort, only 5,921 patients (5.8%) attended CR; 80.2% were male, and the mean age was 62.3 years, with most patients in their 60s, followed by those in their 50s. Of the 96,623 patients (94.2%) who did not attend CR, 70.1% were male, and the mean age was 66.8 years; most patients were in their 60s, followed by those in their 70s. Medical aid beneficiaries attended CR less than health insurance subscribers. The proportions of AMI and UA cases were similar in the CR group, but UA (77.8%) was more common than AMI (35.7%) in the non-CR group. CR was mostly implemented at tertiary hospitals (82.6%) and much less practiced at general hospitals (17.4%). The length of stay in acute hospital settings was longer in the non-CR group (5.52 ± 5.1 days) than in the CR group (4.8 ± 3.9 days). Patients living in urban areas were more likely to attend CR compared to those in rural areas. After 1:1 PS matching, no differences in patient characteristics were noted between the two groups (total, 11,686 patients) for almost all variables, except non-ST elevated myocardial infarction and tertiary hospital status, which were more common in the CR group. Comorbidities of the study participants are summarized in **Table 3**.

Quality of participation among CR attendees of the original cohort

Only 5.84% (5,921) of the 102,544 study patients attended a CR program, either as an inpatient or outpatient. **Table 4** shows the quality of participation among CR attendees (n =

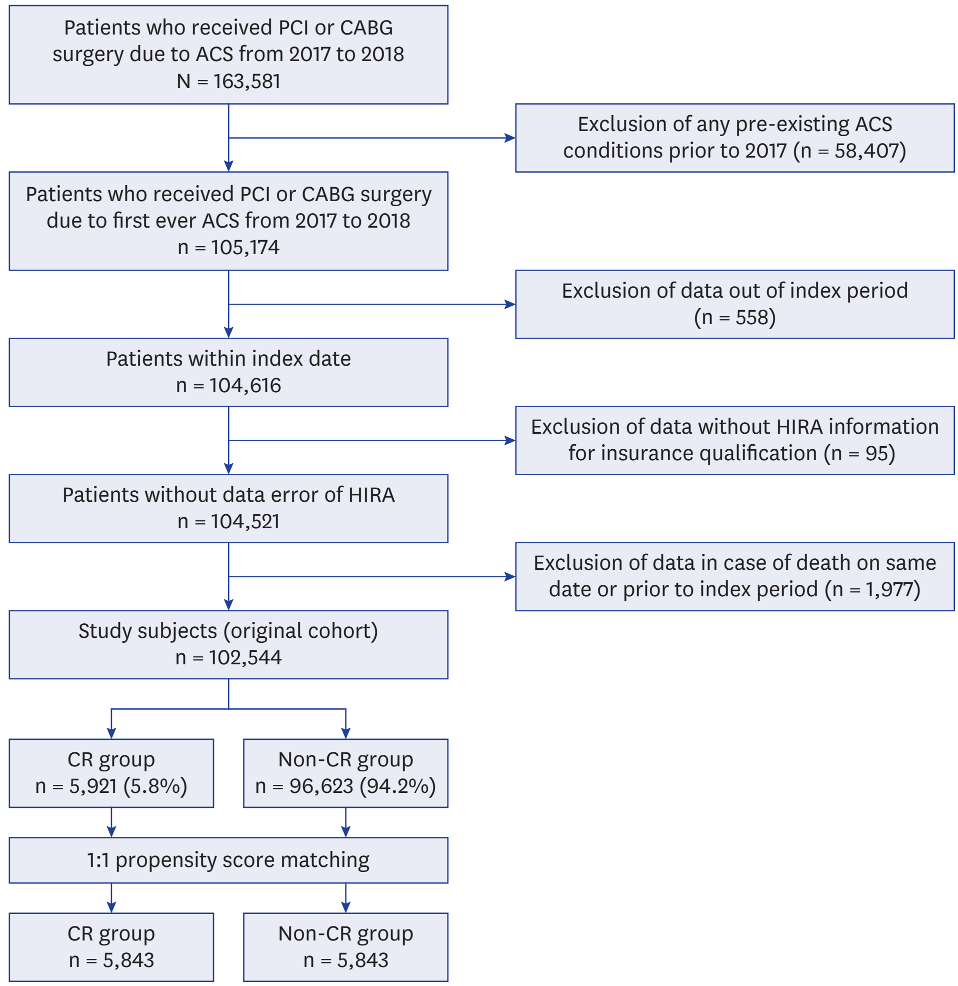

Fig. 1. Flow chart showing the selection of subjects for this study.
PCI = percutaneous coronary intervention, CABG = coronary artery bypass grafting, ACS = acute coronary syndrome, HIRA = Health Insurance Review & Assessment Service, CR = cardiac rehabilitation, MACE = major adverse cardiovascular events.

5,921). In total, 83.58% of patients in the CR group underwent a CR evaluation that included the CPX test, but follow-up CPX tests were not frequently performed; 14.5% and 9% of patients in the CR group undertook the CPX test two and three times, respectively. Regarding monitoring, 3,145 patients (53.12% of the CR group) participated in an electrocardiogram (ECG) monitoring exercise at the hospital. However, over half of them (1,700 patients) participated in only one session; 1,136 patients participated in 2–10 sessions; 187 patients participated in 11–20 sessions; and only 117 patients (1.98% of the CR group) completed 20 or more exercise sessions at the hospital. Further, 46.88% of the patients in the CR group received a CR evaluation or education without exercise training at the hospital, and it is unknown whether the patients correctly adhered to a proper exercise protocol. According to the claim code of MM451, only 23.95% of patients in the CR group received CR education.

Prognostic impact of CR on cardiovascular outcomes after ACS

The 1:1 matching of 5,843 CR and non-CR patients showed that 143 (2.45%) and 223 (3.82%) patients died during the follow-up period, respectively. **Table 5** shows that cardiovascular events including all-cause death, recurred ACS, cardiovascular readmission, and MACE were

Table 2. Characteristics of study participants

Variables	Original cohort			After 1:1 PS matching		
	CR group (n = 5,921)	Non-CR group (n = 96,623)	SMD	CR group (n = 5,843)	Non-CR group (n = 5,843)	SMD
Sex						
Men	4,753 (80.3)	67,691 (70.1)	0.2381	4,690	4,720	−0.0130
Women	1,168 (19.7)	28,932 (29.9)	−0.2381	1,153	1,123	0.0130
Age, yr				62.4 ± 10.7	62.8 ± 10.9	
< 30	5 (0.1)	52 (0.1)	0.0117	5	2	0.0210
30–39	114 (1.9)	829 (0.9)	0.0912	112	114	−0.0025
40–49	625 (10.6)	5,879 (6.1)	0.1624	614	591	0.0129
50–59	1,537 (30)	18,987 (19.7)	0.1508	1,516	1,490	0.0102
60–69	2,055 (34.7)	29,152 (30.2)	0.0970	2,028	2,045	−0.0061
70–79	1,303 (22.0)	28,473 (29.5)	−0.1713	1,286	1,301	−0.0062
Over than 79	282 (4.8)	13,251 (13.7)	−0.3129	282	300	−0.0142
Insurance type						
Health insurance	5,649 (95.4)	88,332 (91.4)	0.1781	5,649	5,668	−0.0186
Medical aid	194 (3.3)	6,954 (7.2)	−0.1781	194	175	0.0186
Diagnosis						
MI	3,022 (51.0)	34,452 (35.7)	0.3142	2,992	2,986	0.0021
NSTEMI	1,713 (28.9)	15,854 (16.4)	0.3025	1,699	1,365	0.1302
Unstable angina	3,691 (62.3)	75,186 (77.8)	−0.3429	3,634	3,625	0.0032
Intervention						
PCI (balloon)	509 (8.6)	8,425 (8.2)	−0.0044	501	467	0.0211
Stent insertion	5,420 (91.5)	88,849 (92)	−0.0151	5,349	5,403	−0.0341
Atherectomy	8 (0.1)	89 (0.1)	0.0128	7	5	0.0107
Thrombolysis	0	5 (0.01)	−0.0102	-	-	0
Bypass surgery	178 (3.0)	1,681 (1.7)	0.0833	176	143	0.0347
Hospital class						
Clinic	1 (0.01)	232 (0.2)	−0.0623	1	8	−0.0432
General hospital	1,028 (17.4)	53,670 (55.5)	−0.8643	1,010	2,952	−0.7498
Tertiary hospital	4,892 (82.6)	42,721 (44.2)	0.8695	4,832	2,883	0.7524
LOS, day				4.8 ± 3.9	4.8 ± 3.5	
< 8	5,215 (88.1)	79,117 (81.9)	0.1740	5,143	5,181	−0.0203
8–14	532 (9.0)	12,040 (12.5)	−0.1125	529	517	0.0072
Over than 14	174 (2.9)	5,466 (5.7)	−0.1343	171	145	0.0274
Residence						
Urban	2,869 (48.5)	41,477 (42.9)	0.1111	2,837	2,867	−0.0103
Rural	3,052 (51.5)	55,142 (57.1)	−0.1111	3,006	2,976	0.0103

Values are presented as number (%) or mean ± standard deviation.
PS = propensity score, CR = cardiac rehabilitation, SMD = standardized mean difference, MI = myocardial infarction regardless of ST-elevation myocardial infarction or non-ST-elevation myocardial infarction, NSTEMI = non-ST-elevation myocardial infarction, PCI = percutaneous coronary intervention, LOS = length of stay in acute hospital setting.

Table 3. Comorbidities of the study participants

Comorbidities	Before PS matching			After PS matching		
	CR group (n = 5,921)	Non-CR group (n = 96,623)	SMD	CR group (n = 5,843)	Non-CR group (n = 5,843)	SMD
Hypertension	4,919 (83.1)	82,650 (85.5)	−0.0677	4,858	4,879	−0.0096
Diabetes	3,696 (62.4)	69,149 (71.6)	−0.1954	3,651	3,665	−0.0050
Dyslipidemia	5,631 (95.1)	92,339 (95.6)	−0.0220	5,556	5,542	0.0110
CKD	814 (13.7)	16,859 (17.4)	−0.1021	802	802	0
CVA	948 (16.0)	23,904 (24.7)	−0.2180	931	921	0.0047
Cancer	1,687 (28.5)	29,241 (30.3)	−0.0389	1,662	1,641	0.0080
COPD	837 (14.1)	18,101 (18.7)	−0.1243	825	805	0.0099

PS = propensity score, CR = cardiac rehabilitation, SMD = standardized mean difference, CKD = chronic kidney disease, CVA = cerebrovascular disease including stroke and transient ischemic attack, COPD = chronic obstructive pulmonary disease.

significantly lower in the CR group than in the non-CR group, after adjusting for potential confounders. **Fig. 2** shows the Kaplan-Meier survival curves for cardiovascular events in both groups during the three-year follow-up period. The survival rates were 96.6% and 94.4%

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Table 4. The quality of CR participation among CR attendees in the original cohort (n = 5,921)

Status of participation in CR program	No. of cases (%)
CR education MM451[a] (risk factor management)	
No	4,503 (76.05)
Yes	1,418 (23.95)
CR evaluation MM452[a] (CPX test)	
No	972 (16.42)
Yes	4,949 (83.58)
Once	2,978 (50.30)
Twice	858 (14.50)
Three times	533 (9.00)
Four times	332 (5.60)
More than five	239 (4.03)
CR therapy MM453[a] (exercise training)	
Only CR education or evaluation	2,776 (46.88)
Monitoring exercise at hospital	3,145 (53.12)
One session only	1,700 (28.72)
2–10 sessions	1,136 (19.19)
11–20 sessions	187 (3.16)
20 or more sessions	117 (1.98)
Maximal (130) sessions	1 (0.01)

CR = cardiac rehabilitation, CPX = cardiopulmonary exercise.
[a]Claim codes for each CR program.

Table 5. Comparison of three-year CV outcomes between the CR and non-CR groups

CV events	CR group (n = 5,843)			Non-CR group (n = 5,843)			*P* value
	No. of event (%)	PY	Per 1,000-PY	No. of event (%)	PY	Per 1,000-PY	
All-cause death	143 (2.45)	11,827	12.1	223 (3.82)	11,725	19	< 0.001
Recurrence of ACS	1,319 (22.57)	9,310	141.7	1,408 (24.10)	9,122	154.4	0.015
Revascularization	640 (10.95)	10,924	58.6	601 (10.29)	11,583	51.9	0.241
CV readmission	1,925 (32.95)	9,172	209.9	2,245 (38.42)	11,155	201.3	< 0.001
MACE	2,286 (39.12)	8,328	274.5	2,661 (45.54)	9,032	294.6	< 0.001

CV = cardiovascular, CR = cardiac rehabilitation, ACS = acute coronary syndrome, MACE = major adverse cardiovascular event, PY = person-year.

(log-rank $P < 0.001$), recurred ACS rates were 23.9% and 25.8% (log-rank $P < 0.00289$), cardiovascular readmission rates were 36.5% and 42.1% (log-rank $P < 0.001$), and MACE rates were 43.3% and 49.8% (log-rank $P < 0.001$) in the CR and non-CR groups, respectively. However, the revascularization rates were not different between the two groups (log-rank $P < 0.2922$). **Table 6** shows the impact of CR on cardiovascular outcomes within three years after ACS in the propensity-score weighted study cohort. The cumulative 3-year HR for all-cause death was 0.612 (95% confidence interval [CI], 0.495–0.756), recurred ACS was 0.92 (95% CI, 0.853–0.993), CR readmission was 0.817 (95% CI, 0.768–0.868), and MACE was 0.827 (95% CI, 0.781–0.874) in the CR group. According to the subgroup analysis, CR was associated with a significant dose-response effect on the cumulative incidence of MACE, with a reduction in MACE incidence from 0.854 to 0.711 (**Fig. 3**, **Table 7**).

DISCUSSION

Clinical practice guidelines for CR have been officially published by many countries, including the United Kingdom, European Union, Canada, United States of America, Japan, and Korea.[5,14-19] However, in spite of the high level of evidence and the strong recommendation for CR, the overall rate of CR participation is only about 30% to 40% globally.[20] According to our study, the actual rate of CR participation in South Korea was only 5.8%. A previous study using KNHIS data reported a much lower rate of only 1.5%[7]

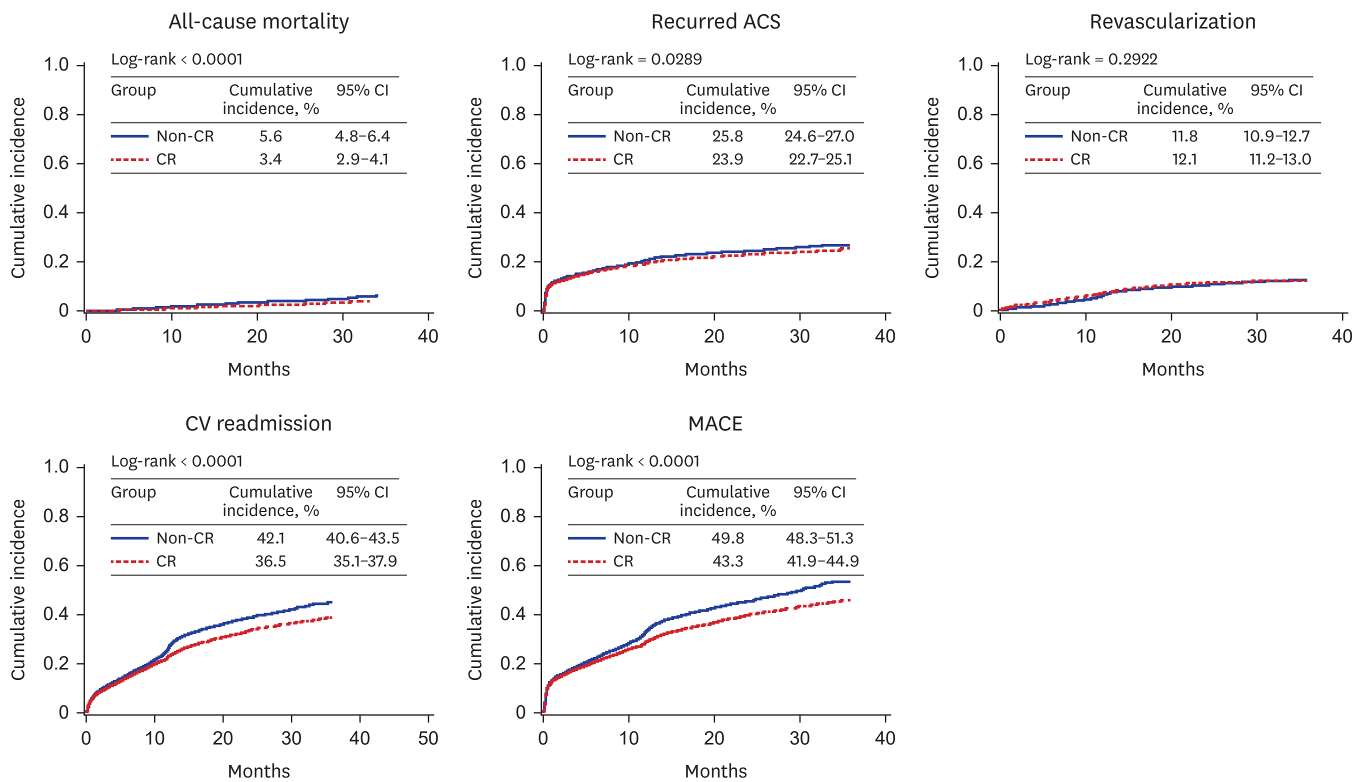

Fig. 2. Kaplan-Meier survival curves of CV outcomes.
ACS = acute coronary syndrome, CR = cardiac rehabilitation, CV = cardiovascular, MACE = major adverse cardiovascular events, CI = confidence interval.

Table 6. The impact of CR on CV outcomes in propensity-score weighted cohort

CV events	HR	95% CI	*P* value
All-cause death			
One year	0.795	0.542–1.165	0.239
Two years	0.608	0.482–0.767	< 0.001
Three years	0.612	0.495–0.756	< 0.001
Recurrence of ACS			
One year	1.060	0.976–1.151	0.167
Two years	0.911	0.844–0.984	0.017
Three years	0.920	0.853–0.993	0.031
Revascularization			
One year	1.386	1.198–1.603	< 0.001
Two years	1.061	0.946–1.191	0.310
Three years	1.077	0.963–1.204	0.195
CV readmission			
One year	1.103	1.023–1.188	0.010
Two years	0.825	0.775–0.879	< 0.001
Three years	0.817	0.768–0.868	< 0.001
MACE			
One year	1.098	1.027–1.174	0.006
Two years	0.838	0.791–0.888	< 0.001
Three years	0.827	0.781–0.874	< 0.001

CR = cardiac rehabilitation, CV = cardiovascular, HR = hazard ratio, CI = confidence interval, ACS = acute coronary syndrome, MACE = major adverse cardiovascular events.

probably due to different study selection criteria, as we included patients with not only AMI but also those with UA and who underwent bypass surgery. We also included both inpatient and outpatient CR participation and more recent KNHIS data, which may imply that the

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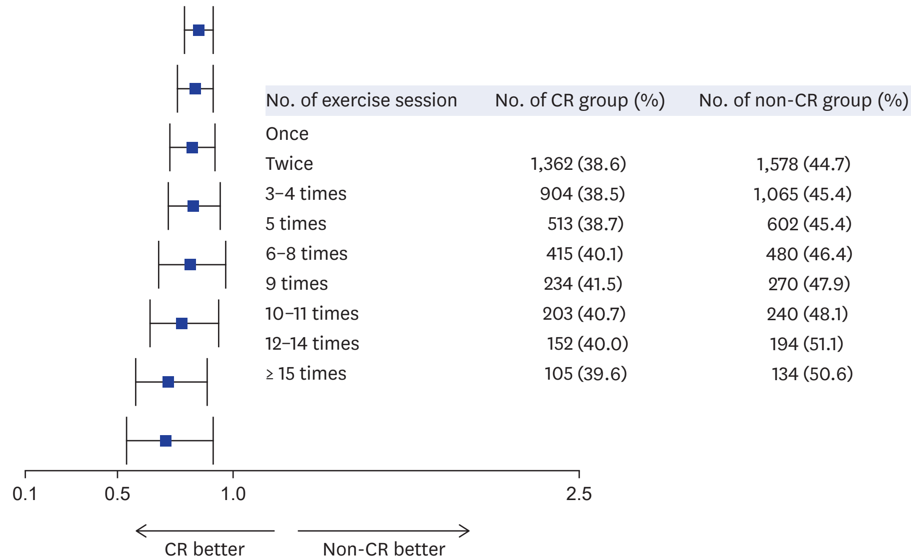

Fig. 3. Dose-response impact of CR on three-year cumulative MACE.
CR = cardiac rehabilitation, MACE = major adverse cardiovascular events.

Table 7. Dose-response impact of CR on three-year cumulative MACE

No. of exercise session, times	HR	95% CI	*P* value
Twice	0.854	0.794–0.919	< 0.000
3–4	0.841	0.769–0.920	< 0.000
5	0.826	0.733–0.930	0.001
6–8	0.832	0.729–0.950	0.006
9	0.817	0.684–0.975	0.025
10–11	0.779	0.645–0.941	0.001
12–14	0.722	0.582–0.895	0.003
≥ 15	0.711	0.547–0.923	0.010

CR = cardiac rehabilitation, HR = hazard ratio, CI = confidence interval, MACE = major adverse cardiovascular events.

CR participation rate had increased with time. In South Korea, CR insurance benefits were introduced in February 2017, and CR facilities have increased by up to 46 centers.[8] Nevertheless, the rate of CR participation in South Korea remains much lower than that in high-income Western countries.[21,22] Therefore, efforts should be made to increase CR participation, including the establishment of new CR facilities in line with the increasing incidence of ACS.[7,23] and active application of efficient strategies to resolve barriers to CR.[6,24,25] To achieve this goal, medical professionals' efforts to improve CR environments and government-initiated strategies to improve CR policy are necessary.

Our study showed that patients in the CR group were more likely to be male, of middle age, health insurance subscribers, treated at tertiary hospitals, urban residents, and have less comorbidity than those in the non-CR group. Sex and age differences are well known issues related to CR participation; therefore, continuous efforts to solve these barriers are needed by providing women and older people a friendly CR environment through educational programs and nationwide campaigns, involving collaboration between hospitals, academic medical societies, and government programs. Paradoxically, medical aid beneficiaries were less likely to attend CR than were health insurance subscribers. According to the KNHIS policy, health insurance subscribers pay 50% of CR fee as allotted charges, but 2nd grade beneficiaries pay 15% and 1st grade beneficiaries pay 5%.[9] Since most medical aid beneficiaries are in the low-income group, they may lack the time and resources to attend CR programs. Therefore, more special advantages or incentives, such as no allotted charges for CR fees, provision of transportation costs, and maintenance grants or special support grants for this group during the period of CR should be considered. There were regional gaps in the CR practice rate when considering the number of annual ACS cases and that most CR facilities are located in the metropolitan area or big cities of South Korea.[8] Therefore, it may be too inconvenient for rural residents (i.e., those from farming/fishing villages, mountainous villages, and islands) to attend a CR program. Therefore, equal distribution of CR facilities and the establishment of CR programs at both tertiary and CVD-specialized general hospitals are also needed.

In addition to the low rate of CR participation, the quality of participation among CR attendees was subpar. While CR evaluations frequently included a CPX test (in 83.58% of the CR group), follow-up CPX tests were not frequently performed; less than half of the CR patients participated in ECG monitoring exercise sessions and only 1.98% (117 patients) completed 20 or more sessions. Moreover, 46.88% of CR attendees received only CR evaluation or education without exercise training at the hospital, mostly due to socio-economic barriers, indicating that active application of a well-organized home-based CR program is needed and that the medical cost for such a program should be reimbursed by the national healthcare systems. We considered patients with claim code MM451 as those who received CR education; therefore, 76.05% (4,503 patients) of the CR attendees were considered to have not received CR education. However, many hospitals may not have processed the claim code MM451 during the time of our study; therefore, this may be a transient phenomenon.[8]

Our study on original claims data of this KNHIS cohort demonstrated that the impact of CR on cardiovascular outcomes was superior to that of usual care after ACS, with follow-up death rates of 2.45% and 3.82% in the matched CR and non-CR groups, respectively. In spite of the short follow-up period, the incidence of all-cause death, recurred ACS, cardiovascular readmission, and MACE were significantly lower in the CR group than in the non-CR group, after adjusting for potential confounders. Interestingly, there was a significant dose-response effect of CR on the cumulative incidence of MACE with MACE incidence reduction from 0.854 to 0.711. Hammill et al.[26] also reported a strong dose-response relationship between the number of CR sessions and long-term outcomes. If the rate and quality of CR participation are improved close to the expected goal, the impact of CR on cardiovascular outcomes may be magnified.

This study has several limitations that should be noted. First, the present study retrospectively reviewed medical records of patients with data linked to national health insurance claims; therefore, the results may have been biased due to various unmeasured confounding factors. Insufficient information on prognostic factors may have influenced the effects of CR, such as the size and location of myocardial infarcts, severity of coronary artery stenosis, time duration of myocardial ischemia, whether PCI was successful, and the presence of heart failure. In addition, the CR group may have shown better adherence to prognostic management than the non-CR group. Furthermore, economic ability, family interest and support, and particularly the patient's baseline functional status would have influenced clinical outcomes. Second, the diagnosis of ACS was operationally defined using medical claims records, and there are possibilities of false exclusion or inclusion. Third, there could be a mismatch between actual performance and the claims record. As mentioned before, our period of index admission was the transient period of insurance benefit for

CR, and incomplete claims for CR, especially CR education, may exist. Fourth, due to the limitation of health insurance claims data, the cause of death was especially difficult to identify. Therefore, cardiovascular mortality could not be distinguished. Nevertheless, this study's finding is consistent with previous related studies, which showed that CR participation has a favorable effect on cardiovascular and all-cause mortality. Fifth, the follow-up period was relatively short (three years) because the claim codes of KNHIS for CR have only been collected since 2017. Therefore, further study is required with various kinds of CR cases for longer follow-up periods using NHIS claim data. Finally, we excluded the claim code AZ110 for CR education analysis, which is also used for CVD education in tertiary hospitals. We analyzed the three new claim codes created when CR insurance benefits were introduced; therefore, CR education may be underestimated since we could not analyze the claim code AZ110 together.

Despite these limitations, this nationwide population-based study is the first report to demonstrate the actual rate and quality of CR participation and the real impact of CR on cardiovascular outcomes. As previously mentioned, CR has only been covered by insurance provided by the Korean government since 2017; therefore, we need more time to establish a national systematic plan for improving CR implementation and a state-controlled CR network. CR participation should be increased through the establishment of new CR facilities and active application of efficient strategies to resolve barriers to CR. In addition, patient-oriented CR programs, such as a patient-preferred home-based CR strategy, should be applied to increase the rate of outpatient CR adherence. However, effective governmental policy and financial support are necessary for these strategies to be realized. Finally, we believe that these study results would be beneficial for use in countries where the status of CR participation is similar to that in South Korea or where CR is yet to be implemented.

In conclusion, the actual rate of hospital-based CR participation after ACS was only 5.8% in South Korea, despite coverage by the NHIS. In addition to low rate of CR participation, the quality of participation among CR attendees was subpar. Nevertheless, the original claims data of the KNHIS cohort revealed that the impact of CR on cardiovascular outcomes was superior to that of usual care after ACS. In spite of the short follow-up period, the incidence of all-cause death was significantly lower in the CR group than in the non-CR group, and CR was associated with a significant dose-response effect on the cumulative incidence of MACE.

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