



Clinical and Economic Outcomes of Korea's National Polypharmacy Management Program for Hospitalized Older Adults: 90-Day Readmission and Healthcare Costs

Suhyun Jang¹ · Jaeok Lim² · Arum Moon² · Ju-Yeun Lee³ · Young-Mi Ah⁴ · Hye Jun Lee⁵ · Sei Young Lee⁶ · Jung-Ha Kim⁵ · Sunmee Jang²

Received: 1 February 2026 / Accepted: 17 July 2026 / Published online: 8 August 2026
© The Author(s) 2026

Abstract

Background Polypharmacy is a significant health concern associated with adverse outcomes in older adults. To mitigate these risks, Korea's National Health Insurance Service implemented a hospital-based, pilot polypharmacy management program. **Objective** We aimed to evaluate the clinical and economic effectiveness of the polypharmacy management program in beneficiaries aged ≥ 65 years.

Methods This retrospective cohort study evaluated the polypharmacy management program implemented across 34 hospitals (2020–21). The program targeted hospitalized patients with at least one chronic condition receiving either ten or more medications or five or more medications plus an additional high-risk factor. To address the lack of randomization, an external historical control group was established by linking pilot data with the nationwide National Health Insurance Service claims database. Propensity score matching was performed on the entire cohort with subsequent analyses restricted to those aged ≥ 65 years. The primary outcome was 90-day readmission, analyzed using Cox proportional hazards regression. A cost–benefit analysis was performed from payer and societal perspectives.

Results The final analysis included 1135 intervention and 1125 control patients. Polypharmacy management program participants showed a lower risk of readmission compared with controls (adjusted hazard ratio = 0.85; 95% confidence interval 0.75–0.96). While emergency department visits did not differ significantly, the intervention group incurred significantly lower hospitalization costs (USD\$6400 vs USD\$6740, $P = 0.005$). The program demonstrated economic viability, yielding a benefit–cost ratio of 3.8 from a payer perspective.

Conclusions The polypharmacy management program effectively reduced readmissions and generated substantial cost savings. These findings underscore the importance of integrating data-driven medication management into national healthcare strategies to improve patient safety and financial sustainability.

1 Introduction

Rapid population aging is reshaping the global demographic landscape. By 2030, one in six people will be aged 60 years or older, with the number of people in the age group

projected to double to 2.1 billion by 2050 [1]. Because age-related physiological changes significantly alter the pharmacokinetics and pharmacodynamics of medications [2], polypharmacy, which refers to the concurrent use of

✉ Jung-Ha Kim
girlpower219@cau.ac.kr

✉ Sunmee Jang
smjang@gachon.ac.kr

¹ College of Pharmacy and Research Institute of Pharmaceutical Sciences, Woosuk University, Wanju, Republic of Korea

² College of Pharmacy and Gachon Institute of Pharmaceutical Sciences, Gachon University, 191 Hambakmoe-ro, Yeonsu-gu, Incheon 21936, Republic of Korea

³ College of Pharmacy, Seoul National University, Seoul, Republic of Korea

⁴ College of Pharmacy, Yeungnam University, Gyeongsan, Republic of Korea

⁵ Department of Family Medicine, College of Medicine, Chung-Ang University, 102 Heukseok-ro, Dongjak-gu, Seoul 06973, Republic of Korea

⁶ Department of Otolaryngology-Head & Neck Surgery, College of Medicine, Chung-Ang University, Seoul, Republic of Korea

Key Points

This multidisciplinary medication management program for hospitalized older adults significantly reduced the risk of 90-day hospital readmissions.

The program demonstrated substantial economic benefits, with savings from reduced healthcare utilization outweighing implementation costs.

Utilizing nationwide health insurance data for targeted medication management offers a scalable and sustainable strategy to optimize healthcare resources in a rapidly aging society.

multiple medications by an individual, has emerged as a critical concern in geriatric care. In South Korea, the prevalence of polypharmacy among individuals aged 75 years and older was approximately 70%, one of the highest rates among OECD (Organisation for Economic Co-operation and Development) countries and well above the OECD average of 46.7% [3]. This is a pressing public health issue that is expected to exacerbate with rapid aging of the population.

Polypharmacy is strongly associated with potentially inappropriate medication use, which elevates the risk of adverse drug events (ADEs) and compromised health outcomes [4–7]. The resulting burden is substantial: ADEs account for approximately one in ten hospitalizations in older adults [8], drug-related problems drive a disproportionate share of emergency department (ED) visits and emergency admissions in this population [9, 10], and recurrent ADEs after discharge—many of them preventable—contribute to readmission and functional decline [11–14]. These events also impose a considerable economic burden, largely driven by preventable inpatient costs [15, 16].

In response to these challenges, healthcare professionals and policymakers have prioritized precise intervention to optimize medication use. Prominent among these strategies is comprehensive medication management, designed to optimize medication for older adults during hospitalization [17]. Comprehensive medication management involves a systematic assessment of a patient's medication, considering critical factors such as potential drug interactions, therapeutic duplications, appropriate dosing, and alignment with personalized health goals. Specifically, studies regarding medication reconciliation (MR)—a key component of comprehensive medication management—have reported noteworthy reductions in preventable ADEs within 30 days of discharge [18]. Furthermore, a systematic review and meta-analysis of pharmacist-led MR demonstrated substantial reductions in adverse event-related

hospital visits (relative risk [RR] = 0.33; 95% confidence interval [CI] 0.20–0.53), all-cause ED visits (RR = 0.72; 95% CI 0.57–0.92), and all-cause readmissions (RR = 0.81; 95% CI 0.70–0.95) [19]. In addition to these clinical benefits, MR has been associated with notable advantages in healthcare costs [20–22].

Since 2020, the Korean National Health Insurance Service (NHIS) has implemented a pilot polypharmacy management program (PMP) in secondary or tertiary hospital settings to reduce the health risks associated with polypharmacy. Under this program, a multidisciplinary team comprising physicians, pharmacists, and nurses provides medication management services for eligible participants, including MR upon admission and patient education at discharge. To support its delivery, the NHIS pays participating hospitals a dedicated service fee under the pilot program, set with reference to the fee schedule of the pre-existing chronic disease management program. The program has expanded progressively since its launch, and a recent report examined the medication-related problems identified and resolved through the intervention [23]. However, its impact on the clinical and economic outcomes of the target population has not yet been evaluated.

Despite the expansion of the PMP, comprehensive evidence regarding its impact on the target population—older adults—remains limited. Prior evaluations of MR have largely been confined to single institutions or Western healthcare settings and have focused predominantly on clinical endpoints, whereas economic evaluations within a real-world nationwide context remain scarce. This study aimed to evaluate the clinical and economic effectiveness of the PMP, specifically targeting patients aged 65 years and older. We utilized the NHIS claims database, which provides comprehensive coverage of the entire Korean population's healthcare utilization. To mitigate selection bias inherent to observational studies, we established a comparable control group using propensity score matching. Our analysis primarily focused on hospital readmission rates as a key clinical outcome. Furthermore, we assessed the program's economic feasibility and potential for national scalability within the Korean healthcare context.

2 Methods

2.1 Polypharmacy Management Program in Hospitals

As a pilot initiative by the NHIS, a multidisciplinary medication management intervention was implemented for hospitalized patients deemed to require comprehensive medication management. This collaborative management

was conducted by a multidisciplinary team comprising physicians, pharmacists, and nurses.

The inclusion criteria for program participants were as follows:

1. Enrollees in the National Health Insurance (NHI) diagnosed with at least one of 46 predefined chronic conditions (Table 1 of the Electronic Supplementary Material [ESM]); AND
2. Patients meeting either of the following criteria:
3. Prescribed ten or more medications.
4. Prescribed five or more medications and deemed to require management by healthcare providers. High-risk factors prompting this inclusion included a history of ED visits within the previous 6 months, the use of one or more high-risk drugs, or the prescription of five or more new medications during hospitalization. High-risk drugs were predefined as non-steroidal anti-inflammatory drugs, diuretics, digoxin, anticoagulants, dual antiplatelet therapy, three or more antihypertensive agents, insulin or three or more oral hypoglycemic agents, antidepressants, two or more anticholinergic agents, three or more central nervous system-depressant agents, corticosteroids (≥ 20 mg of prednisolone equivalent), and opioid analgesics in non-cancer patients.

While adhering to inclusion criteria, hospitals exercised clinical discretion in selecting eligible participants based on individualized patient context. To facilitate a comprehensive review, the NHIS provided hospitals with a 6-month history of medical utilization and prescription records for each selected patient. Using these data, pharmacists conducted medication reviews and consultations during hospitalization. When medication-related problems requiring intervention were identified, recommendations were provided to the attending physician or the relevant department. For prescriptions prescribed by external institutions, recommendations were conveyed directly to the patient or caregiver. For the study population, the evaluated intervention comprised the inpatient and pre-discharge components described below; a post-discharge follow-up, such as telephone-based medication management, was not part of the intervention evaluated in this study. The detailed intervention protocol proceeded as follows: for the present study population, the evaluated intervention comprised these inpatient and pre-discharge components only (Steps 1 and 2); no post-discharge follow-up, such as telephone-based medication management, was part of the evaluated program.

Step 1. Medication review and reconciliation: during hospitalization, eligible participants were identified, and the program was introduced. Following the provision of

information and obtaining informed consent, pharmacists conducted a comprehensive medication assessment, utilizing the 6-month medication history integrated from the NHIS claims database. This process involved formulating medication plans, engaging in medication consultations, and performing necessary prescription reconciliations based on both the patient's history and current hospital prescriptions.

Optional functional assessment: a standardized functional evaluation was defined in the program protocol and performed by a physician when judged clinically necessary. The protocol-specified domains comprised medical problem evaluation, clinical frailty (e.g., Clinical Frailty Scale), and cognitive function.

Step 2. Pre-discharge evaluation: prior to discharge, a comprehensive follow-up evaluation was conducted. This included a review of prescribed medications, further consultations, and planning for post-discharge management.

- Review of discharge prescriptions: pharmacists thoroughly examined post-discharge medications based on the prescriptions administered during the hospital stay and the patient's clinical condition.
- Monitoring of medication-related issues: any issues identified during the initial inpatient consultation were continuously monitored for resolution or management.
- Adherence counseling and discharge planning: consultation regarding medication adherence and future management plans were conducted, taking into account the patient's preferences and care requirements.

2.2 Study Population

The study cohort comprised patients hospitalized in program-participating hospitals between 2020 and 2021. The program enrolled 504 participants from seven institutions in 2020 and 1860 participants from 33 institutions in 2021 (2364 in total). Although each annual program cycle extended from August through July of the following year, claims data covering admissions during the March-July period were not fully available at the time of analysis. To ensure a complete 90-day post-discharge observation window for all patients, the cohort was restricted to those with an index admission between August and February, yielding 1939 participants eligible for 3-month post-discharge monitoring. These patients were selected as program beneficiaries and underwent a medication review and reconciliation during hospitalization. Eligible patients were identified among all hospitalized patients meeting the program criteria, irrespective of admission route (elective or emergency).

Inclusion and exclusion criteria: inclusion criteria for the outcome evaluation were as follows: (1) survival for 7

Table 1 Baseline characteristics of propensity score-matched participants and external controls aged 65 years and older

Category	Variable		Participants (<i>n</i> = 1135)		Controls (<i>n</i> = 1125)		SMD
			<i>N</i>	%	<i>N</i>	%	
Strata	Hospital	Tertiary hospital	762	67.1	737	65.5	0.034
		General hospital	373	32.9	388	34.5	0.034
	Specialty	Internal medicine	837	73.7	836	74.3	0.014
		Neurology	129	11.4	119	10.6	0.026
		Orthopedic surgery	98	8.6	93	8.3	0.011
		Neurosurgery	28	2.5	31	2.8	0.019
		General surgery	14	1.2	13	1.2	0.000
		Physical medicine and rehabilitation	14	1.2	13	1.2	0.000
		Thoracic surgery	11	1.0	18	1.6	0.053
		Urology	4	0.4	2	0.2	0.037
	Month of index date	Aug–Oct	513	45.2	511	45.4	0.004
		Nov–Dec	421	37.1	419	37.2	0.002
		Jan–Feb	201	17.7	195	17.3	0.011
PSM	Age, years	Mean (SD)	75.9	6.8	76.1	6.9	0.029
		65–74	502	44.2	482	42.8	0.028
		75–84	511	45.0	517	46.0	0.020
		≥ 85	122	10.7	126	11.2	0.016
	CCI	Mean (SD)	2.2	1.6	2.0	1.5	0.129
		0	123	10.8	121	10.8	0.000
		1	263	23.2	294	26.1	0.067
		2	220	19.4	212	18.8	0.015
		≥ 3	529	46.6	498	44.3	0.046
	ICU	Yes	202	17.8	232	20.6	0.071
	Diagnosis at index admission	Cancer	142	12.5	127	11.3	0.037
	No. of medications	Mean (SD)	12.6	6.6	11.6	6.4	0.154
		0–9	385	33.9	463	41.2	0.151
		10–14	338	29.8	325	28.9	0.020
		15–19	254	22.4	207	18.4	0.099
		≥ 20	158	13.9	130	11.6	0.069
		History of hospitalization	Yes	566	49.9	594	52.8
	History of ED visit	Yes	232	20.4	269	23.9	0.084
Covariate	Sex	Male	637	56.1	616	54.8	0.026
		Female	498	43.9	509	45.2	0.026
	Disable	No	847	74.6	850	75.6	0.023
		Yes	288	25.4	275	24.4	0.023
	LTC grade	No	959	84.5	931	82.8	0.046
		Yes	176	15.5	194	17.2	0.046
	NHI premium (quintile)	1 (lowest)	180	15.9	324	28.8	0.313
		2	138	12.2	90	8.0	0.140
		3	156	13.7	111	9.9	0.118
		4	226	19.9	197	17.5	0.062
		5 (highest)	435	38.3	403	35.8	0.052
	Pre-admission comorbidity	Cardiovascular disease	121	10.7	102	9.1	0.054
		Cerebrovascular disease	44	3.9	61	5.4	0.071
		Cancer	153	13.5	172	15.3	0.051
	Diagnosis at index admission	Cardiovascular disease	199	17.5	136	12.1	0.153
		Cerebrovascular disease	84	7.4	106	9.4	0.072

Table 1 (continued)

Category	Variable	Participants (<i>n</i> = 1135)		Controls (<i>n</i> = 1125)		SMD	
		<i>N</i>	%	<i>N</i>	%		
	LOS at index admission	Mean (SD)	13.7	13.0	14.7	17.6	0.065
	Medication	Anticoagulants	138	12.2	96	8.5	0.119
		Benzodiazepines	141	12.4	110	9.8	0.084
		Dementia medications	308	27.1	245	21.8	0.125
		PIM	595	52.4	519	46.1	0.126

The discrepancy in sample size (*n* = 1135 vs *n* = 1125) is due to the exclusion of matched individuals under 65 years of age. SMDs were computed from the reported group statistics; SMD < 0.1 indicates adequate balance

CCI Charlson Comorbidity Index, ED emergency department, ICU intensive care unit, LOS length of stay, LTC long-term care, NHI National Health Insurance, PIM potentially inappropriate medication, PSM propensity score matching, SD standard deviation, SMD standardized mean difference

or more days post-discharge; (2) no history of coronavirus disease 2019 (International Classification of Diseases, Tenth Revision code U07.1; defined as two or more outpatient claims or one or more inpatient claims with this diagnosis) from 1 year prior to admission through the follow-up period; and (3) a hospital stay of 3 days or more. To ensure statistical stability, hospitals with fewer than ten participants and departments with fewer than five participants were excluded from the analysis. The index date was set as the date of admission.

Control group selection: as this program was implemented as a pilot project without a predefined control group, we established an external historical control group to evaluate effectiveness, adhering to relevant guidelines [24]. Given that patients excluded from the pilot program during the intervention period were likely to have lower clinical severity or fewer medication management needs, using concurrent controls could introduce selection bias. Therefore, patients hospitalized in the same participating hospitals and medical specialty during the year prior to the program's implementation were selected as the control group. This design allowed us to control for institutional variables and represent the standard of care prior to the intervention.

Propensity score matching: to ensure comparability between the intervention and historical control groups, propensity scores were calculated by logistic regression in the overall cohort, including age group, Charlson Comorbidity Index (CCI) category, intensive care unit admission, cancer diagnosis at index admission (primary or secondary diagnosis; cancer vs non-cancer), history of hospitalization and ED visits during the previous year, and number of medications. Optimal 1:1 matching without replacement was then performed, requiring exact agreement on the participating hospital, medical specialty, year of participation, and season of admission, and minimizing the propensity score distance within the common support region. No caliper was applied.

Matching was conducted on the entire cohort to maximize comparability; subsequent analyses were strictly restricted to the primary target population aged ≥ 65 years, consistent with the clinical focus of the PMP. Because age group was explicitly included as a propensity score covariate, the age distribution was balanced prior to this restriction, and the post-restriction sample retained covariate balance (Table 1). As the age restriction removed the matched controls of the excluded younger participants, the final analytic sample size differed slightly between the two groups (intervention, *n* = 1135; control, *n* = 1125).

2.3 Data

This study utilized a linked dataset combining the PMP participant registry and the nationwide NHIS claims database. The PMP registry was employed to identify the intervention cohort and participation details, while the NHIS database provided longitudinal clinical data and analytical variables. The NHIS is a mandatory single-payer system covering the entire Korean population. Under the mandatory designation system, all healthcare providers and pharmacies are required to participate in the NHIS. The database contains comprehensive records of inpatient and outpatient care, as well as prescriptions. The claims data include socio-demographics, disability status, mortality, healthcare costs, and service utilization (diagnoses, tests, procedures, and long-term care services) [25]. This integration of pilot program data with nationwide claims records ensures high data completeness, minimizing loss to follow-up and enabling robust tracking of healthcare outcomes across all medical institutions. As the pilot PMP was implemented and funded under the NHI program, eligibility was limited to NHI beneficiaries; both the study population and the historical control group therefore comprised NHI beneficiaries only.

2.4 Health Outcomes

Health outcomes were assessed over a 90-day follow-up period, commencing 2 days post-discharge to exclude immediate transfers or administrative readmission. The outcomes of interest included all-cause hospital readmission, ED visits, and outpatient visits. In addition to the individual outcomes, a composite outcome was defined as the first occurrence of either hospital readmission or an ED visit during the 90-day follow-up period.

Readmission: defined as any inpatient admission (scheduled or via ED).

ED visits: defined as visits to the ED that did not result in hospitalization (i.e., the patient was discharged on the same day).

Outpatient visits: assessed solely based on the frequency of outpatient visits.

For readmissions and ED visits, both the incidence and length of stay (LOS) were analyzed, whereas, only the frequency was considered for outpatient visits.

2.5 Covariates

To maximize comparability, exact matching was performed for the following structural variables: institution type, medical specialty (internal medicine, neurology, orthopedics, neurosurgery, surgery, rehabilitation, thoracic surgery, and urology), participation year (2020 vs 2021, and season of admission (August–October, November–December, January–February; index admissions did not fall within March–July, as the analytic window was limited by the timing of data acquisition and the 90-day follow-up requirement).

The propensity score was estimated using the following matching covariates: age group (65–74, 75–84, ≥ 85 years), CCI category (0, 1, 2, ≥ 3), intensive care unit admission, a cancer diagnosis (primary or secondary) at the index admission, number of medications prior to admission, and a history of hospitalization and ED visits during the previous year.

In addition to these matching covariates, the multivariable Cox proportional hazards models were adjusted for institution type (tertiary vs general hospital), sex, disability status, long-term care eligibility, NHI premium quintile, cardiovascular, cerebrovascular, and cancer diagnoses (primary or secondary) recorded at the index admission and during the prior year, LOS at the index admission, use of anticoagulants, benzodiazepines, and dementia medications, and potentially inappropriate medication use. Potentially inappropriate medications were identified based on the 2019 American Geriatrics Society Beers Criteria [26].

2.6 Costs

Total direct medical costs incurred post-discharge were categorized into hospitalization, ED, outpatient, and pharmacy costs. To account for skewed cost data (where some patients incurred zero costs in specific categories), median costs were calculated for the overall population and separately for those with non-zero expenditures. All costs were adjusted to 2022 values based on the annual adjustment rate of NHIS service fees. The intervention cost (program cost) was derived from the service fees paid by the NHIS to participating hospitals under the pilot PMP during the study period. These fees were set with reference to the fee schedule of the pre-existing NHIS chronic disease management program, applied to the corresponding PMP service components (initial inpatient assessment and care planning, optional patient functional assessment, and pre-discharge consultation).

2.7 Cost–Benefit Analysis

The economic analysis focused on estimating the benefits of the PMP, defined as the avoided costs resulting from prevented negative health outcomes and reduced healthcare utilization. Benefits were categorized into direct and indirect savings. Direct benefits were calculated by estimating the cost savings from reduced hospitalizations, using the average hospitalization costs of the control group to represent the status quo. Indirect benefits, included in the societal perspective analysis, comprised avoided transportation and caregiving expenses due to reduced healthcare utilization. Transportation savings were calculated by multiplying the reduction in hospitalization events by a round-trip cost of USD\$24, derived from the Korean Medical Panel Survey. Caregiving savings were estimated based on the Korean Health Experience and Assessment Survey, incorporating an 8.4% utilization rate of paid caregivers among adults aged ≥ 60 years, a caregiver usage duration ratio of 0.75 per hospitalization day, and a daily cost of USD\$79. Productivity loss was excluded from the analysis, as the study population consisted of individuals aged ≥ 65 years, most of whom were assumed to be retired.

The cost–benefit model compared total costs and benefits in 2022 values between the PMP and non-PMP scenarios from both payer and societal perspectives. To estimate the nationwide impact, we assumed an annual target of 89,520 participants, based on the capacity of 373 secondary and tertiary hospitals in Korea (as of 2022) managing 20 cases per month [27]. No discount rate was applied given the 1-year analysis horizon. Sensitivity analyses were performed to assess the robustness of the results against parameter uncertainty. The uncertainty of the program's effectiveness using the upper and lower limits of the 95% CI of the estimated

hazard ratio (HR), while direct medical benefits were varied by $\pm 25\%$ to test the stability of the estimates.

2.8 Statistical Analysis

Baseline characteristics were presented using descriptive statistics; continuous variables were expressed as means with standard deviations, and categorical variables were expressed as numbers and percentages. Covariate balance after matching and after the age restriction was assessed using standardized mean differences (SMDs), with an absolute value below 0.1 considered indicative of adequate balance [28]. For matching covariates with a residual SMD between 0.1 and 0.25, the imbalance was addressed through adjustment in the multivariable models, as an imbalance in this range is generally considered amenable to regression adjustment [29, 30]. The incidence of outcome events within the 90-day follow-up period was examined for each individual, and the mean LOS for readmission and outpatient visits were calculated. To visualize the time to first readmission and ED visits post-discharge, Kaplan–Meier survival curves were generated for both groups, with differences assessed using the log-rank test. Multivariable Cox proportional hazards regression models were employed to estimate the risks of hospitalization and ED visits after adjusting for potential confounders, which were selected a priori on the basis of clinical relevance and prior literature rather than by data-driven statistical cut-offs. All statistical analyses were

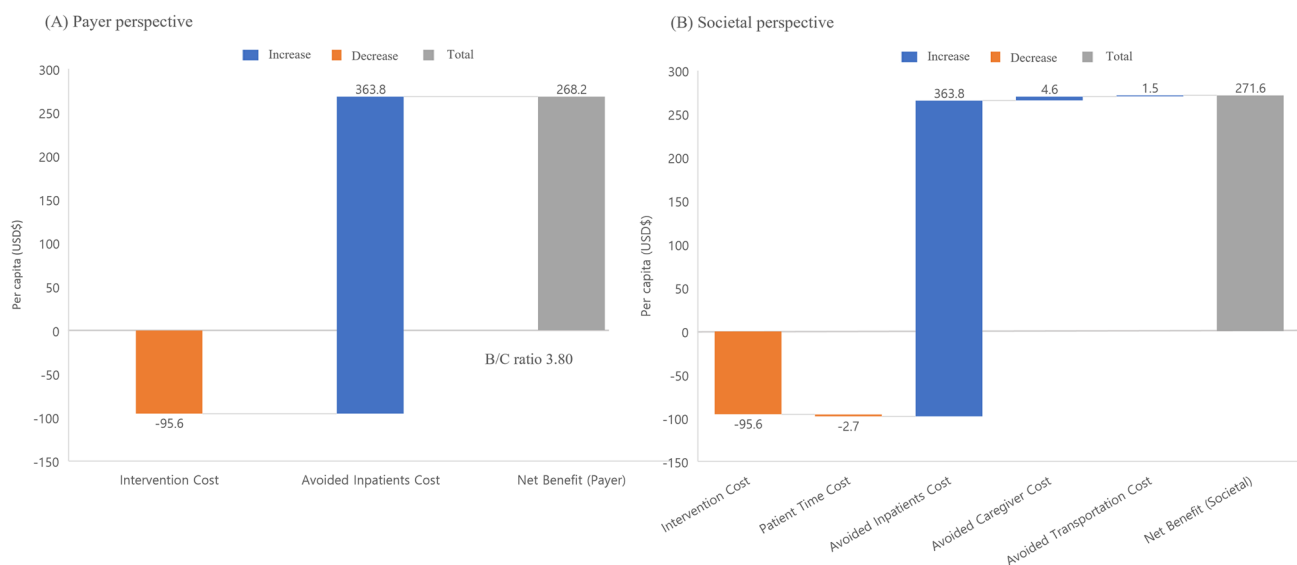
conducted using SAS software (Version 9.4; SAS Institute, Inc., Cary, NC, USA). All statistical tests were two-sided, and a P value < 0.05 was considered statistically significant.

3 Results

3.1 Characteristics of Study Participants

In 2020 and 2021, 2364 individuals participated in the pilot PMP. After restriction to index admissions with a complete 90-day observation window (August–February) and application of the selection criteria, 1468 eligible participants were identified. Propensity score matching (1:1) was initially performed on the full cohort to maximize comparability, generating 1465 matched pairs. However, given that the final analysis was restricted to participants aged ≥ 65 years, the resulting sample size differed slightly between the groups (intervention $n = 1135$ vs controls $n = 1125$), as the paired controls for excluded younger patients were omitted from this subgroup analysis (Fig. 1 of the ESM).

The baseline characteristics are summarized in Table 1. The variables used for exact matching—participation year, month of admission, healthcare institution, and medical specialty—were well balanced between groups. The majority of participants (67.1%) were treated in tertiary general hospitals, and the Department of Internal Medicine accounted for the largest proportion (73.7%). The mean age of the



Estimated annual cost–benefit analysis of the polypharmacy management program. This waterfall chart illustrates the projected economic impact of a nationwide implementation, based on a hypothetical annual cohort of 89,520 participants. **A** Analysis from the payer perspective, considering only direct medical costs and benefits. **B** Analysis from the societal perspective, incorporating indirect costs (patient

time) and benefits (caregiver and transportation savings). Orange bars indicate investment costs (negative values), while blue bars represent monetized benefits derived from avoided healthcare utilization (positive values). The gray bars depict the net economic benefit, with benefit–cost (B/C) ratios of 3.80 and 3.76, respectively. All values are presented in 2022 US Dollars (USD)

intervention group was 75.9 years (standard deviation 6.8). Most covariates were well balanced after matching (SMD < 0.1). The two matching covariates with a residual SMD between 0.1 and 0.25 were the CCI and the number of medications. Among the non-matching adjustment covariates, income level showed the largest imbalance (SMD > 0.25), while several others—including the use of anticoagulants and dementia medications and potentially inappropriate medication use—had SMDs between 0.1 and 0.25; all were included as covariates in the multivariable models. The remaining covariates were well balanced (SMD < 0.1).

3.2 Post-discharge Health Outcomes

Table 2 summarizes the health outcomes within 3 months post-discharge. The readmission rate was significantly lower in the intervention group compared with the control group (42.9% vs 47.5%; $P = 0.029$). Similarly, the mean number of readmissions per patient was significantly lower in the intervention group (0.8 ± 1.2 vs 0.9 ± 1.3 ; $P = 0.012$). However, the LOS for readmission did not differ significantly between the groups (14.7 ± 19.2 days vs 14.8 ± 24.0 days; $P = 0.916$). Regarding ED visits, differences in the proportion of patients visiting the ED (6.4% vs 8.4%; $P = 0.068$) and the mean number of visits per person (0.1 ± 0.5 vs 0.2 ± 0.9 ; $P = 0.050$) did not reach statistical significance, although a borderline trend toward reduction was observed.

The Kaplan–Meier survival curves (Fig. 2 of the ESM) showed significant differences in the cumulative incidence of the composite outcome (readmission or ED visit; $P = 0.029$) and readmission alone ($P = 0.049$), favoring the intervention group. However, no significant difference was found for ED visits ($P = 0.232$). Both crude and adjusted Cox proportional hazard regression analyses revealed that the risk of the composite outcome was significantly lower in the intervention group compared with the control group (crude HR 0.88, 95% CI 0.78–0.99; adjusted HR 0.84; 95% CI 0.74–0.95) [Table 3]. The crude and adjusted estimates were

Table 2 Comparison of 90-day post-discharge health outcomes between polypharmacy management program participants and external controls

	Participants ($n = 1135$)		Controls ($n = 1125$)		P value
Readmission, n (%)	487	(42.9)	534	(47.5)	0.029
No. of readmissions, mean (SD)	0.76	(1.2)	0.89	(1.3)	0.012
LOS, mean (SD)	14.7	(19.2)	14.8	(24.0)	0.916
ED visit, n (%)	73	(6.4)	95	(8.4)	0.068
No. of ED visits, mean (SD)	0.10	(0.5)	0.16	(0.9)	0.050
No. of outpatient visits, mean (SD)	12.2	(11.3)	11.5	(10.6)	0.130

ED emergency department, LOS length of stay, SD standard deviation

closely aligned, indicating robustness to covariate adjustment. Specifically, the risk of readmission was significantly lower in the intervention group (adjusted HR 0.85; 95% CI 0.75–0.96), whereas no significant difference was observed for ED visits (adjusted HR 0.86; 95% CI 0.64–1.16).

3.3 Cost Outcomes

The estimated direct intervention cost per participant was estimated at USD\$95.6, while the indirect cost (attributed to patient time) was USD\$2.7, based on the analysis of program implementation data (Table 3 of the ESM). Post-discharge healthcare expenditures were classified into four categories: hospitalization, ED, outpatient, and pharmacy costs (Table 2 of the ESM). In the overall population, the median costs of hospitalization and ED visits were zero, as the majority of patients did not utilize these services during the follow-up period.

Among patients with non-zero expenditures, the intervention group incurred significantly lower per capita hospitalization costs compared with the control group (USD\$6400 vs USD\$6740; $P = 0.005$). Conversely, pharmacy costs were significantly higher in the intervention group (USD\$445 vs controls USD\$334; $P < 0.001$). Outpatient costs were higher in the intervention group, but this difference did not reach statistical significance (USD\$401 vs USD\$377; $P = 0.069$).

3.4 Cost–Benefit Analysis

A cost–benefit analysis was conducted to evaluate the economic impact of PMP (Fig. 1 and Table 3 of the ESM). Based on a projected annual target of 89,520 participants

Table 3 Crude and adjusted HRs for 90-day post-discharge outcomes

	Crude HR (95% CI)	Adjusted HR (95% CI)
Composite outcome	0.88 (0.78–0.99)	0.84 (0.74–0.95)
Readmission	0.88 (0.78–1.00)	0.85 (0.75–0.96)
ED visit	0.84 (0.63–1.12)	0.86 (0.64–1.16)

The composite outcome was defined as the first occurrence of either hospital readmission or an ED visit during the 90-day follow-up period

Adjusted HR is estimated after adjusting for institution type (tertiary vs general hospital), sex, age, disability status, long-term care service eligibility, insurance premium quintile, CCI, ICU, number of hospitalization and ED visits in the previous year, LOS at index admission, pre-admission comorbidities (cardiovascular disease, cerebrovascular disease, and cancer), diagnosis at index admission (cardiovascular disease, cerebrovascular disease, and cancer), number of medications taken, medications (anticoagulants, benzodiazepines, and dementia medications), and PIM use

CCI Charlson Comorbidity Index, CI confidence interval, ED emergency department, HR hazard ratio, ICU intensive care unit, LOS length of stay, PIM potentially inappropriate medication

(as detailed in the Methods), the total direct cost of the program was estimated at USD\$8,559,786. Additionally, the total societal cost, which incorporates the indirect cost of patient time, was calculated to capture the broader economic implications.

Direct economic benefits, primarily derived from avoided inpatient costs due to reduced readmissions, were estimated at USD\$364 per participant, totaling USD\$32,565,337 for the entire projected population. Indirect benefits, comprising avoided caregiver and transportation costs, totaled USD\$546,322.

From a payer perspective (considering direct program costs and direct benefits), the net benefit was estimated at USD\$24,005,551 (USD\$268.2 per participant), yielding a benefit-cost ratio of 3.80. From a societal perspective (incorporating indirect costs and benefits), the net benefit was estimated at USD\$24,307,947 (USD\$271.5 per participant), with a benefit-cost ratio of 3.76. These results consistently demonstrate that the economic benefits of the PMP substantially outweigh the costs across both perspectives. The sensitivity analyses confirmed the robustness of these findings, confirming consistent economic benefits across alternative scenarios (Table 4 of the ESM).

4 Discussion

This study contributes to the extant body of evidence by empirically assessing the efficacy of a nationwide PMP tailored for hospitalized older adults. We conducted a thorough investigation into the multifaceted effects of the PMP on health outcomes, coupled with a rigorous cost-benefit analysis using NHIS claims data. A key strength of this intervention is that it is underpinned by a collaborative multidisciplinary model, involving physicians, pharmacists, and nurses, to address the complex medication regimens of older adults.

The implementation of such a program is particularly timely in South Korea, where polypharmacy poses a critical public health challenge. South Korea ranks among the top three OECD countries for polypharmacy prevalence, with 70.2% of individuals aged 75 years and older affected—a figure significantly higher than the OECD average of 46.2% for the same age group [3]. Our findings demonstrate that the PMP had a substantial positive impact on health outcomes, particularly by reducing preventable hospital readmissions. This underscores the clinical value of targeted medication reviews and reconciliation performed by a multidisciplinary team.

Our findings regarding hospital readmission corroborate a recent meta-analysis on the impact of MR, which reported a significant reduction in the risk of readmission (RR 0.81; 95% CI 0.70–0.95) [19]. Similarly, a controlled study in Hong Kong reported significantly lower 1-month

readmission rates in the MR group compared with usual care (13.2% vs 29.1%; $P = 0.005$) [31]. However, a notable distinction exists regarding ED utilization. While the aforementioned meta-analysis observed a reduction in ED visits (RR 0.72; 95% CI 0.57–0.92), our study observed only a non-significant trend. This discrepancy suggests that while the PMP is highly effective in stabilizing patients for discharge to prevent readmission, additional strategies, such as enhanced community-based monitoring, may be required to reduce acute ED utilization.

Beyond clinical improvements, our analysis revealed a favorable cost-benefit profile, lending support to prior economic evaluations. Previous work by Najafzadeh et al. identified the potential for substantial cost savings with a net benefit of USD\$206 per patient, driven by a reduction in preventable ADEs [32]. Our results extend this perspective, confirming that cost savings were largely achieved through decreased readmissions and shortened hospital stays. These findings are consistent with international evidence. Brookes et al. estimated that MR prevented significant readmissions, translating to an annual cost saving of £80,000 [33]. Notably, a pharmacy practice model demonstrated the potential to prevent approximately 75 high-risk readmissions annually; this yielded total estimated savings of USD\$1,121,850 when including overhead costs [34]. Furthermore, reductions in LOS have been consistently linked to economic benefits across various healthcare systems. Studies have reported estimated annual savings of over £3 million in the UK [35] and USD\$9839 over 5 months in a South Korea tertiary hospital [36]. Similarly, in China, MR following orthopedic surgery was shown to significantly reduce LOS from 20.3 to 16.3 days ($P = 0.03$), resulting in savings of USD\$1833 per hospitalization [37]. This aligns with recent evidence identifying readmissions as the primary cost driver in medication management programs [38]. Collectively, these data reinforce the economic viability of the PMP alongside its clinical efficacy. Our findings provide valuable insights into the implications of implementing a PMP initiative within a NHI system. The rapid global shift towards an aging society underscores the urgent need for refined medication management for older adults. The PMP represents a proactive and strategic response to the potential risks associated with polypharmacy, aiming to enhance the quality of care for hospitalized older patients.

However, barriers to the widespread expansion of such programs remain [39, 40]. These include challenges in consolidating patient medication histories across institutions, gaps in interprofessional communication, workforce shortages, patient resistance to potential co-payments, and difficulties in ensuring continuity of care with community pharmacists. Nevertheless, the PMP in South Korea distinguished itself by utilizing the centralized NHIS data infrastructure to meticulously manage participant selection

and comprehensive medication history reviews [41]. Furthermore, the program successfully fostered collaboration among skilled professionals within multidisciplinary teams in general hospitals. Since its introduction in 2020 with seven hospitals, the program has expanded to 48 hospitals in 2023 and 74 hospitals in 2025, providing services to approximately 5744 patients, with a planned target of up to approximately 6500 patients in 2026. From the payer's perspective, our cost–benefit analysis indicates that the service fee paid for the intervention was more than offset by the resulting savings (benefit–cost ratio 3.8), supporting the economic justification of the current fee. Whether this fee level adequately covers the providers' service costs, and thus sustains hospital participation as the program scales nationwide, remains an important question for future evaluation. Taken together, these findings suggest that systematic data utilization, institutional integration, and multidisciplinary collaboration, along with attention to a financially sustainable payment structure, are pivotal to the success and continued expansion of the national-level polypharmacy programs.

This study has several limitations. First, as the PMP was implemented as a pilot project without randomization, we established an external historical control group and applied exact and propensity score matching within the same institutions. Because matching was performed on the overall population, restricting the final analysis to those aged ≥ 65 years yielded unequal group sizes. Most covariates were well balanced (SMD < 0.1); the two matching covariates with a residual SMD of 0.1–0.25 (CCI and number of medications), together with several non-matching covariates showing larger imbalances, were addressed through adjustment in the Cox models. As the intervention group had higher baseline clinical complexity, these imbalances would bias the comparison toward the null, and the close concordance between crude and adjusted estimates supports robustness. Furthermore, although a broad range of epidemiologic and clinical characteristics available in claims data were matched or adjusted for, claims data lack clinical information such as laboratory values and functional status, and certain conditions that commonly precipitate hospitalization in older adults, such as chronic respiratory disease (e.g., chronic obstructive pulmonary disease and pneumonia), were not specifically adjusted for. Given the observational design and historical control, residual or unmeasured confounding cannot be entirely excluded. Second, our analysis was confined to a short-term follow-up period (3 months post-discharge), precluding the assessment of long-term implications. Third, post-discharge medication adherence and potential discrepancies in the community setting were not monitored; thus, their influence could not be quantified. This reflects the scope of the program during the study period, which extended up to the pre-discharge consultation;

notably, the program has since incorporated a post-discharge telephone-based follow-up for selected patients, which may help address this gap and warrants evaluation in future studies. Fourth, this study focused primarily on evaluating the average treatment effect of the PMP at the national level, and did not delineate the varying clinical and economic impacts across specific patient subgroups or detailed clinical phenotypes. Further investigation is warranted in future follow-up studies to identify which specific patient populations (e.g., based on detailed comorbidity profiles, high-risk medication combinations, or frailty levels) benefit most from the program, which will help optimize target criteria and resource allocation. Finally, regarding the societal perspective cost–benefit analysis, productivity loss costs were excluded. However, given that our study population consisted of older adults (aged ≥ 65 years), most of whom are retired, the exclusion of productivity loss is likely to have a negligible impact on the overall estimates.

5 Conclusions

A PMP significantly improves health outcomes among hospitalized older adults, particularly by reducing preventable readmissions. The rigorous cost–benefit analysis indicates that scaling up the program nationwide could yield substantial economic benefits, with returns outweighing costs by nearly four-fold. These findings underscore the importance of integrated medication management in addressing the complexities of polypharmacy and enhancing the financial sustainability of healthcare delivery in an aging society.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s40266-026-01325-6>.

Acknowledgements We extend our gratitude to the Chronic Disease Management Division of the Department of Medical Utilization Management at the National Health Insurance Service for their assistance in implementing the program and providing the data.

Funding Open Access funding enabled and organized by Chung-Ang University Hospital.

Declarations

Funding This research was supported by the National Health Insurance Service (NHIS-2022-1-558). This study was also supported by Woosuk University.

Conflicts of interest/competing interests Suhyun Jang, Jaeok Lim, Arum Moon, Ju-Yeun Lee, Young-Mi Ah, Hye Jun Lee, Sei Young Lee, Jung-Ha Kim, and Sunmee Jang have no conflicts of interest that are directly relevant to the content of this article.

Ethics approval This study was approved by the Gachon University Institutional Review Board (Approval No. 1044396-202205-HR-107-01).

Consent to participate Informed consent was waived by the institutional review board because the study involved a retrospective analysis of anonymized administrative data.

Consent for publication Not applicable.

Availability of data and material Data were obtained from a third party and are not publicly available.

Code availability Not applicable.

Authors' contributions Conceptualization: Jang S (Suhyun Jang), Lim J, Kim JH, Jang S (Sunmee Jang). Data curation: Jang S (Suhyun Jang), Lee JY, Ah YM, Lee HJ, Kim JH, Jang S (Sunmee Jang). Formal analysis: Jang S (Suhyun Jang), Lim J. Funding acquisition: Kim JH. Investigation: Jang S (Suhyun Jang), Lim J, Moon A, Lee JY, Ah YM, Lee HJ, Lee SY, Kim JH, Jang S (Sunmee Jang). Project administration: Kim JH, Jang S (Sunmee Jang). Supervision: Kim JH, Jang S (Sunmee Jang). Writing (original draft): Jang S (Suhyun Jang). Writing (review and editing): Lim J, Moon A, Lee JY, Ah YM, Lee HJ, Lee SY, Kim JH, Jang S (Sunmee Jang). All authors have read and approved the final submitted manuscript and agree to be accountable for all aspects of the work.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, which permits any non-commercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc/4.0/>.

References

1. World Health Organization. Ageing and health. Geneva: World Health Organization; 2022. <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health>. Accessed 26 July 2026.
2. Shah BM, Hajjar ER. Polypharmacy, adverse drug reactions, and geriatric syndromes. *Clin Geriatr Med*. 2012;28:173–86. <https://doi.org/10.1016/j.cger.2012.01.002>.
3. OECD. Health at a glance 2021: OECD indicators. Paris: OECD Publishing; 2021. <https://doi.org/10.1787/ae3016b9-en>.
4. Fialová D, Topinková E, Gambassi G, Finne-Soveri H, Jónsson PV, Carpenter I. Potentially inappropriate medication use among elderly home care patients in Europe. *JAMA*. 2005;293:1348–58. <https://doi.org/10.1001/jama.293.11.1348>.
5. Maher RL, Hanlon J, Hajjar ER. Clinical consequences of polypharmacy in elderly. *Expert Opin Drug Saf*. 2014;13:57–65. <https://doi.org/10.1517/14740338.2013.827660>.
6. Steinman MA, Seth Landefeld C, Rosenthal GE, Berthenthal D, Sen S, Kaboli PJ. Polypharmacy and prescribing quality in older people. *J Am Geriatr Soc*. 2006;54:1516–23. <https://doi.org/10.1111/j.1532-5415.2006.00889.x>.
7. Davies LE, Spiers G, Kingston A, Todd A, Adamson J, Hanratty B. Adverse outcomes of polypharmacy in older people: systematic review of reviews. *J Am Med Dir Assoc*. 2020;21:181–7. <https://doi.org/10.1016/j.jamda.2019.10.022>.
8. Oscanoa TJ, Lizaso F, Carvajal A. Hospital admissions due to adverse drug reactions in the elderly. A meta-analysis. *Eur J Clin Pharmacol*. 2017;73:759–70. <https://doi.org/10.1007/s00228-017-2225-3>.
9. Budnitz DS, Lovegrove MC, Shehab N, Richards CL. Emergency hospitalizations for adverse drug events in older Americans. *N Engl J Med*. 2011;365:2002–12. <https://doi.org/10.1056/NEJMs1103053>.
10. Budnitz DS, Shehab N, Lovegrove MC, Geller AI, Lind JN, Pollock DA. US emergency department visits attributed to medication harms, 2017–2019. *JAMA*. 2017;326:1299–309. <https://doi.org/10.1001/jama.2021.13844>.
11. Boyd CM, Ricks M, Fried LP, Guralnik JM, Xue QL, Xia J. Functional decline and recovery of activities of daily living in hospitalized, disabled older women: the Women's Health and Aging Study I. *J Am Geriatr Soc*. 2009;57:1757–66. <https://doi.org/10.1111/j.1532-5415.2009.02455.x>.
12. Kanaan AO, Donovan JL, Duchin NP, Field TS, Tjia J, Cutrona SL. Adverse drug events after hospital discharge in older adults: types, severity, and involvement of Beers Criteria medications. *J Am Geriatr Soc*. 2013;61:1894–9. <https://doi.org/10.1111/jgs.12504>.
13. Szlejf C, Farfel JM, Curiati JA, Couto EB, Jacob-Filho W, Azevedo RS. Medical adverse events in elderly hospitalized patients: a prospective study. *Clinics (Sao Paulo)*. 2012;67:1247–52. [https://doi.org/10.6061/clinics/2012\(11\)04](https://doi.org/10.6061/clinics/2012(11)04).
14. Zhang M, Holman CD, Price SD, Sanfilippo FM, Preen DB, Bulsara MK. Comorbidity and repeat admission to hospital for adverse drug reactions in older adults: retrospective cohort study. *BMJ*. 2009;338:a2752. <https://doi.org/10.1136/bmj.a2752>.
15. Chiatti C, Bustacchini S, Furneri G, Mantovani L, Cristiani M, Misuraca C. The economic burden of inappropriate drug prescribing, lack of adherence and compliance, adverse drug events in older people: a systematic review. *Drug Saf*. 2012;35:73–87. <https://doi.org/10.1007/BF03319105>.
16. Wu C, Bell CM, Wodchis WP. Incidence and economic burden of adverse drug reactions among elderly patients in Ontario emergency departments: a retrospective study. *Drug Saf*. 2012;35:769–81. <https://doi.org/10.1007/BF03261973>.
17. Griesse-Mammen N, Hersberger KE, Messerli M, Leikola S, Horvat N, van Mil JWF. PCNE definition of medication review: reaching agreement. *Int J Clin Pharm*. 2018;40:1199–208. <https://doi.org/10.1007/s11096-018-0696-7>.
18. Schnipper JL, Barsky EE, Shaykevich S, Fitzmaurice G, Pendergrass ML. Inpatient management of diabetes and hyperglycemia among general medicine patients at a large teaching hospital. *J Hosp Med*. 2006;1:145–50. <https://doi.org/10.1002/jhm.96>.
19. Mekonnen AB, McLachlan AJ, Brien JA. Pharmacy-led medication reconciliation programmes at hospital transitions: a systematic review and meta-analysis. *J Clin Pharm Ther*. 2016;41:128–44. <https://doi.org/10.1111/jcpt.12364>.
20. Cho US, Song YJ, Jung YM, Choi KS, Lee E, Lee E. Effects of medication reconciliation and cost avoidance analysis by clinical pharmacists in a neurocritical care unit. *J Neurocrit Care*. 2018;11:110–8. <https://doi.org/10.18700/jnc.180064>.
21. Herledan C, Baudouin A, Larbre V, Gahbiche A, Dufay E, Alquier I. Clinical and economic impact of medication reconciliation in cancer patients: a systematic review. *Support Care Cancer*. 2020;28:3557–69. <https://doi.org/10.1007/s00520-020-05400-5>.

22. Uhlenhopp DJ, Aguilar O, Dai D, Ghosh A, Shaw M, Mitra C. Hospital-wide medication reconciliation program: error identification, cost-effectiveness, and detecting high-risk individuals on admission. *Integr Pharm Res Pract*. 2020;9:195–203. <https://doi.org/10.2147/IPRP.S269857>.
23. Chae H, Ah Y-M, Jang S, Jang S, Lee HJ, Kim J-H, et al. Resolving medication-related problems in older adults through a multidisciplinary approach in Korea's hospital-based polypharmacy program. *Yonsei Med J*. 2026;67(2):154–64. <https://doi.org/10.3349/ymj.2025.0077>.
24. Ministry of Food and Drug Safety. Considerations for the design and conduct of externally controlled trials (draft) [guideline for civil petitioners]. Cheongju: Ministry of Food and Drug Safety; 2025. https://www.mfds.go.kr/brd/m_1060/view.do?seq=15819&srchFr=&srchTo=&srchWord=&srchTp=&itm_seq_1=0&itm_seq_2=0&multi_itm_seq=0&company_cd=&company_nm=&page=1. Accessed 26 July 2026.
25. National Health Insurance Sharing Service. Customized DB. 2024. <https://nhiss.nhis.or.kr/bd/ab/bdaba032eng.do>. Accessed 26 July 2026.
26. American Geriatrics Society Beers Criteria Update Expert P. American Geriatrics Society 2019 updated AGS Beers Criteria for potentially inappropriate medication use in older adults. *J Am Geriatr Soc*. 2019;67(4):674–94. <https://doi.org/10.1111/jgs.15767>.
27. National Health Insurance Service & Health Insurance Review and Assessment Service. 2022 National Health Insurance statistical yearbook. Wonju: National Health Insurance Service & Health Insurance Review and Assessment Service; 2023. <https://www.nhis.or.kr/nhis/together/wbhaec06300m01.do>. Accessed 26 July 2026.
28. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med*. 2009;28(25):3083–107. <https://doi.org/10.1002/sim.3697>.
29. Rubin DB. Using propensity scores to help design observational studies: application to the tobacco litigation. *Health Serv Outcomes Res Methodol*. 2001;2(3):169–88. <https://doi.org/10.1023/A:1020363010465>.
30. Stuart EA. Matching methods for causal inference: a review and a look forward. *Stat Sci*. 2010;25(1):1–21. <https://doi.org/10.1214/09-STS313>.
31. Chiu KC, Lee WK, See YW, Chan HW. Outcomes of a pharmacist-led medication review programme for hospitalised elderly patients. *Hong Kong Med J*. 2018;24:98–106. <https://doi.org/10.12809/hkmj176871>.
32. Najafzadeh M, Schnipper JL, Shrank WH, Kymes S, Brennan TA, Choudhry NK. Economic value of pharmacist-led medication reconciliation for reducing medication errors after hospital discharge. *Am J Manag Care*. 2016;22:654–61.
33. Brookes K, Scott MG, McConnell JB. The benefits of a hospital based community services liaison pharmacist. *Pharm World Sci*. 2000;22:33–8. <https://doi.org/10.1023/A:1008713304892>.
34. Anderegg SV, Wilkinson ST, Couldry RJ, Grauer DW, Howser E. Effects of a hospitalwide pharmacy practice model change on readmission and return to emergency department rates. *Am J Health Syst Pharm*. 2014;71:1469–79. <https://doi.org/10.2146/ajhp130686>.
35. Scullin C, Scott MG, Hogg A, McElnay JC. An innovative approach to integrated medicines management. *J Eval Clin Pract*. 2007;13:781–8. <https://doi.org/10.1111/j.1365-2753.2006.00753.x>.
36. Park B, Baek A, Kim Y, Suh Y, Lee J, Lee E. Clinical and economic impact of medication reconciliation by designated ward pharmacists in a hospitalist-managed acute medical unit. *Res Social Adm Pharm*. 2022;18:2683–90. <https://doi.org/10.1016/j.sapharm.2021.06.005>.
37. Zheng X, Xiao L, Li Y, Qiu F, Huang W, Li X. Improving safety and efficacy with pharmacist medication reconciliation in orthopedic joint surgery within an enhanced recovery after surgery program. *BMC Health Serv Res*. 2022;22:448. <https://doi.org/10.1186/s12913-022-07884-9>.
38. Robinson EG, Gyllenstein H, Johansen JS, Havnes K, Granas AG, Bergmo TS. A trial-based cost-utility analysis of a medication optimization intervention versus standard care in older adults. *Drugs Aging*. 2023;40:1143–55. <https://doi.org/10.1007/s40266-023-01077-7>.
39. Shin W, Song JS, Kim J. Polypharmacy management program: current status and emerging challenges in older patients. *Korean J Clin Geriatr*. 2021;22:55–60. <https://doi.org/10.15656/kjcg.2021.22.2.55>.
40. Griva K, Chua ZY, Lai LY, Xu SJ, Bek ESJ, Lee ES. Pharmacist-led medication reconciliation service for patients after discharge from tertiary hospitals to primary care in Singapore: a qualitative study. *BMC Health Serv Res*. 2024;24:357. <https://doi.org/10.1186/s12913-024-10830-6>.
41. Shin W, Kim S, Kim J, Song JS. Awareness of and experience in a polypharmacy management program for older inpatients: a qualitative study of patients, caregivers, physicians, and pharmacists. *Korean J Geriatr Gerontol*. 2024;25:22–38. <https://doi.org/10.15656/kjgg.2024.25.1.22>.