Aging Clinical and Experimental Research (2022) 34:445–454
https://doi.org/10.1007/s40520-021-01946-4

ORIGINAL ARTICLE

Associations between inappropriate medication use and (instrumental) activities of daily living in geriatric rehabilitation inpatients: RESORT study

Elizabeth Manias[1,2] · Cheng Hwee Soh[3] · Md. Zunayed Kabir[3] · Esmee M. Reijnierse[3,4] · Andrea B. Maier[3,5,6,7]

Received: 9 February 2021 / Accepted: 29 July 2021 / Published online: 9 August 2021

Abstract

Background Inappropriate medication use can affect functional independence in older adults.

Aims The aim of the study is to examine associations between potentially inappropriate medication use and Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) in geriatric rehabilitation inpatients.

Methods A longitudinal, prospective, observational study was undertaken at a teaching hospital. Potentially inappropriate medications (PIMs) and potential prescribing omissions (PPOs) were measured at acute admission, and at admission and discharge from geriatric rehabilitation. Associations between PIM and PPO use and ADL and IADL scores were examined at admission to geriatric rehabilitation, discharge and 3-month post-discharge.

Results A total of 693 inpatients were included. At the 3-month post-discharge, PPOs were associated with lower IADL scores (incident rate ratio = 0.868, 95% CI 0.776–0.972). There were no significant associations between PIMs and PPOs use at admission to geriatric rehabilitation with longitudinal changes of ADLs and IADLs from geriatric rehabilitation admission to 3-month post-discharge Renal PIMs were associated with higher IADL scores at 3-month post-discharge (incidence rate ratio = 1.750, 95% CI 1.238–2.474). At 3-month post-discharge, PPOs involving vaccinations were associated with a lower IADL score (incident risk ratio = 0.844, 95% CI 0.754–0.944).

Conclusions Inappropriate medication use involving PPOs was associated with lower IADL scores at 3-month post-discharge from geriatric rehabilitation but not with ADL scores. Greater attention is needed in reducing PPOs in geriatric rehabilitation inpatients that can potentially impact IADLs. In the community, health professionals need to be vigilant about assessing how older patients' physical functioning may be affected by inappropriate medication prescribing.

Keywords Aged · Inappropriate prescribing · Activities of daily living · Medication therapy management · Potentially inappropriate medication list · Rehabilitation

✉ Elizabeth Manias
emanias@deakin.edu.au

1 School of Nursing and Midwifery, Centre for Quality and Patient Safety Research, Institute for Health Transformation, 221 Burwood Highway, Burwood, VIC 3125, Australia

2 Department of Medicine, The Royal Melbourne Hospital, The University of Melbourne, 300 Grattan Street, Parkville, VIC 3050, Australia

3 Department of Medicine and Aged Care, @AgeMelbourne, The Royal Melbourne Hospital, The University of Melbourne, 300 Grattan Street, Parkville, VIC 3050, Australia

4 Department of Rehabilitation Medicine, Amsterdam UMC, Amsterdam Movement Sciences, Vrije Universiteit Amsterdam, De Boelelaan 1118, 1081 HZ Amsterdam, The Netherlands

5 @AgeAmsterdam, Department of Human Movement Sciences, Faculty of Behavioural and Movement Sciences, Amsterdam Movement Sciences, Vrije Universiteit Amsterdam, Van der Boechorststraat 7, 1081 BT Amsterdam, The Netherlands

6 Healthy Longevity Translational Research Program, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore

7 Centre for Healthy Longevity, @AgeSingapore, National University Health System, Singapore, Singapore

Introduction

Inappropriate medications can occur from either potentially inappropriate medications (PIMs), where the risk of prescribing medications outweigh the potential benefits, or from potential prescribing omissions (PPOs) where there is a failure to prescribe medications with an obvious benefit [1]. The prevalence of potentially inappropriate medications in older adults is relatively high. In a recent prospective cohort observation study of older people in geriatric and internal medicine wards, the prevalence of PIMs at hospital discharge was 54.8% while the prevalence of PPOs was 47.3% [2].

Inappropriate medications can lead to greater health care utilisation, such as increased hospitalization and emergency department visits [3] and higher health care costs [4] due to adverse drug reactions [5, 6]. Limited knowledge exists on the potential effects of PIMs and PPOs on physical function or the trajectory of functional measures during patients' hospitalization [7]. Activities of daily living (ADL) and instrumental ADL (IADL) are important indicators of physical function, which have a major impact on quality of life and functional independence [8]. ADLs include fundamental skills needed to manage patients' physical needs such as dressing, toileting, and personal hygiene, whereas IADLs include more complex activities such as managing finances or medications, and going shopping [9]. Gaps in past work involve the examination of associations between PIMs and PPOs with ADL and IADL scores for patients admitted to and discharged from geriatric rehabilitation settings. Increased understanding of these associations may help to identify strategies for improving older patients' ability to undertake self-care tasks, during geriatric rehabilitation hospitalization and after discharge.

The aim of this study was to examine the associations between PIMs and PPOs and ADLs and IADLs from admission to 3-month post-discharge in geriatric rehabilitation inpatients.

Methods

Study design and setting

REStORing health of acutely unwell adulTs (RESORT) is a longitudinal, prospective, observational cohort study. The first 693 consented patients of Wave 1 (15th of October 2017 until the 31st of August 2018) were included in the current analysis.

Patients were included if they were admitted to the geriatric rehabilitation wards of the Royal Melbourne Hospital, a tertiary teaching hospital in Melbourne, Australia. Patients were excluded from the study if informed consent was not provided or if they received palliative care at admission. This study was approved by the Melbourne Health Human Research Ethics Committee, Melbourne, Victoria, Australia (No. HREC/17/MH/103) and follows the guidelines outlined in the Declaration of Helsinki.

Patient characteristics

Age, sex, length of acute stay, and length of geriatric rehabilitation stay were extracted from medical records. Morbidity data were captured and assessed by physicians at admission to geriatric rehabilitation wards using the Charlson Comorbidity Index (CCI) [10] with a maximum attainable score of 37, and the Cumulative Illness Rating Scale (CIRS) [11], comprising the severity of diseases with a maximum score of 56 points. Higher scores on the CCI and CIRS indicate higher morbidity and higher disease severity, respectively. Cognitive impairment was consolidated by a dementia diagnoses documented in medical records or by a standardised Mini-Mental State Examination (sMMSE) [12] score of < 24 points, Montreal Cognitive Assessment (MoCA) [13] score < 26 points or Rowland Universal Dementia Assessment Scale (RUDAS) [14] score < 23 points. The Clinical Frailty Scale [15] indicates the frailty level of an individual with a maximum score of 9 showing terminal illness. The Short Physical Performance Battery (SPPB) was completed via physiotherapists, which includes the assessment of standing balance in three positions, a 4-m walk test and the timed chair stand test. Scores range from 0 to 12 with higher scores indicating a higher level of physical function [16].

Potentially inappropriate medication use

Patients' medication data were extracted from discharge summaries or medication charts at three different time points—at admission to the acute wards, at admission to the geriatric rehabilitation wards and at discharge from the geriatric rehabilitation wards. The Screening Tool of Older Person's prescriptions (STOPP) and Screening Tool to Alert to Right Treatment (START) criteria, version 2 [7] were used to assess prescriptions that patients were using at three time points and they were used to measure PIMs and PPOs, respectively. The total number and types of inappropriate medications were recorded for each patient.

Activities of daily living and instrumental activities of daily living

ADL and IADL levels were measured by occupational therapists using the Katz Index (for ADL) [17] and the Lawton and Brody Scale (for IADL) [18]. Time points for completing the

tools were 2-week prior to hospitalization, admission to the geriatric rehabilitation, discharge from geriatric rehabilitation, and at 3-month post-discharge, where a phone call was completed by a trained researcher. The maximum ADL score is six points and the maximum IADL score is eight points, where lower scores indicating higher dependency [17, 18].

Data analysis

Descriptive statistical analyses were undertaken comprising means and standard deviations for continuous variables with a normal distribution or medians and the corresponding interquartile ranges for continuous variables without a normal distribution. Frequency counts and percentages were calculated for discrete variables. The associations between PIMs and PPOs with ADL and IADL scores were analyzed using Poisson regression analyses to produce crude models and two adjusted models (model 1 adjusted for age, sex, and CCI; model 2 adjusted for age, sex, CCI, and baseline ADL and IADL score at 2-week prior to hospitalization). Associations were calculated between PIM and PPO counts at a previous setting and ADL and IADL scores identified in subsequent settings. Hence, PIM or PPO counts at acute admission were examined for associations with ADL or IADL scores at admission to geriatric rehabilitation, at discharge from geriatric rehabilitation and at 3-month post-discharge. PIM and PPO counts at admission to geriatric rehabilitation were examined for associations at discharge from geriatric rehabilitation and at 3-month post-discharge. PIM or PPO counts at discharge from geriatric rehabilitation were examined for associations with ADL or IADL scores at 3-month post-discharge. The associations between PIMs and PPOs use at admission to geriatric rehabilitation with the longitudinal changes of ADLs and IADLs from geriatric rehabilitation to 3-month post-discharge were then assessed using the Generalized Linear Mixed Model with the Poisson distribution. In determining the associations between the PIMs or PPOs and ADLs or IADLs, the total counts for PIMs or PPOs at a particular time point were used. In analysis where the intent was to examine the associations of PIMs or PPOs on ADLs and IADLs for specific body systems of the STOPP and START, the total count of PIMs or PPOs for each body system was used. Results were presented as incident rate ratios (IRR) with 95% confidence intervals (CI). *p* values below 0.05 were considered statistically significant. Statistical analysis was conducted using IBM SPSS for Windows, version 26.0 (Armonk NY: IBM Corp).

Results

Demographic and medication information

The median age was 83.3 (IQR 77.6–87.8) years and 56.6% were female. The median CCI and CIRS scores were 2 (IQR 1–4) and 11 (IQR 8–15), respectively at admission to geriatric rehabilitation. The median length of stay was 7 days (IQR 4–11) for the acute admission and 20 days (IQR 14–29) for the admission in geriatric rehabilitation. The median number of medications prescribed was 9 medications (IQR 6–12) at acute admission, 10 medications (IQR 7–13) at admission to geriatric rehabilitation and 10 medications (IQR 8–13) at discharge from geriatric rehabilitation (Table 1).

The percentage of patients with at least one PIM was 68.7% at the acute admission, 63.9% at admission to geriatric rehabilitation and 60.0% at discharge from geriatric rehabilitation (Table 2). The percentage of patients with at least one PPO was 72.2% at acute admission, 75.6% at admission to geriatric rehabilitation and 72.4% at discharge from geriatric rehabilitation (Table 2).

The three most common PIMs were psychotropic medications associated with the risk of falls, cardiovascular

Table 1 Patient characteristics

Characteristics	*n*	
Age (years)	693	83.3 [77.6–87.8]
Female, *n* (%)	693	392 (56.6)
Length of acute stay (days)	693	7 [4–11]
Length of geriatric rehabilitation stay (days)	693	19.8 [13.6–29.2]
CCI score (points)	693	2 [1–4]
CIRS score (points)	693	11 [8–15]
Cognitive impairment, *n* (%)	693	441 (63.6)
Clinical Frailty Scale score (points)	613	6 [5–7]
SPPB score (points)	658	1 [0–4]
Number of medications		
Acute admission	693	9 [6–12]
Admission to geriatric rehabilitation	693	10 [7–13]
Discharge from geriatric rehabilitation	693	10 [8–13]

All measurements are given as mean (SD) or median [IQR] unless stated otherwise

CCI Charlson Comorbidity Index, *CIRS* Cumulative Illness Rating Scale, *SPPB* Short Physical Performance Battery

Table 2 Prevalence and the number of potentially inappropriate medications (PIMs) and potential prescribing omissions (PPOs), and activities of daily living (ADL) and instrumental activities of daily living (IADL) scores across time points

	Acute admission	Geriatric rehabilitation admission	Geriatric rehabilitation discharge	3-month post-discharge	*p* value
PIMs					
At least one PIM, *n* (%)	476 (68.7)	443 (63.9)	416 (60.0)	N/A	**0.003**
Number of PIMs	1 [0–2]	1 [0–2]	1 [0–2]	N/A	0.826
PPOs					
At least one PPO, n (%)	500 (72.2)	524 (75.6)	502 (72.4)	N/A	0.270
Number of PPOs	2 [0–3]	2 [1–3]	2 [0–3]	N/A	0.712
ADL and IADL					
ADL (score)	N/A	2 [1–3]	4 [1–6]	4 [2–5]	**0.002**
IADL (score)	N/A	1 [0–1]	2 [1–4]	2 [1–5]	**0.031**

Boldness of p values indicate results for $p < 0.05$

All measurements are given as mean ± SD or median [IQR] unless stated otherwise

PIM potentially inappropriate medications, *PPO* potential prescribing omissions, *ADL* activities of daily living, *IADL* instrumental activities of daily living

medications, and analgesic medications. Psychotropic medications comprised benzodiazepines and neuroleptic agents that increased the risk of falls, where 110 (14.4%) patients had at least one of this type of PIM. Cardiovascular medications involved loop diuretics as first-line treatment for hypertension, loop diuretics for dependent ankle oedema without evidence of heart, liver or renal failure, or nephrotic syndrome, and thiazide diuretics in the presence of severe hypokalaemia, where 66 (9.5%) patients had at least one of this type of PIM. Analgesic medications comprised oral or transdermal strong opioids used as therapy for mild pain, where 62 (8.9%) patients had at least one of this type of PIM. Common PIM drug interactions involved duplicate prescriptions of angiotensin converting enzyme inhibitors, or duplicate prescriptions of anticoagulants, which accentuated the potential for adverse effects, where at least 274 (39.5) patients had at least one of this type of PIM.

The three most common PPOs were vaccines, cardiovascular medications, and musculoskeletal medications. Vaccines involved the seasonal influenza vaccine and the pneumococcal vaccine, where 318 (45.9%) patients had at least one of this type of PPO. Cardiovascular medications comprised angiotensin converting enzyme (ACE) inhibitors in the presence of systolic heart failure or coronary artery disease or beta-blockers in the presence of ischaemic heart disease, where 195 (28.1%) patients had at least one of this type of PPO. Musculoskeletal medications comprised bisphosphonates, vitamin D and calcium in patients taking long-term systemic corticosteroid therapy, the use of vitamin D supplements in older people who were housebound, experiencing falls or with osteopenia, and the use of bone antiresorptive or anabolic therapy in patients with documented osteoporosis, 163 (23.5%) had this type of PPO.

Inappropriate medications and activities of daily living

The total number of PIMs and PPOs at all-time points was not associated with ADL scores at geriatric rehabilitation admission, at geriatric rehabilitation discharge and at 3-month follow-up (Table 3). PIM use on acute admission was associated with a higher IADL score at geriatric rehabilitation discharge (incidence rate ratio = 1.139, 95% CI 1.026–1.265, $p = 0.014$). PIM use at geriatric rehabilitation discharge was associated with a lower IADL score at 3-month post-discharge (incidence rate ratio = 0.877, 95% CI 0.788–0.976, $p = 0.016$) (Table 4). After adjusting for age, sex, CCI score, and baseline IADL score, only PIMs use on acute admission remained to be significantly associated with higher IADL score at geriatric rehabilitation discharge (incidence rate ratio = 1.165, 95% CI 1.048–1.294, $p = 0.005$). The presence of PPOs at all-time points was associated with lower IADL at the 3-month post-discharge but not with IADL scores at geriatric rehabilitation admission or discharge. Specifically, PPOs on acute admission (incidence rate ratio = 0.849, 95% CI 0.759–0.950, $p = 0.004$), at geriatric rehabilitation admission (incidence rate ratio = 0.874, 95% CI 0.779–0.980, $p = 0.022$), and at geriatric rehabilitation discharge (incidence rate ratio = 0.815, 95% CI 0.730–0.911, $p < 0.001$), were associated with a lower IADL score at the 3-month post-discharge. After adjusting for age, sex, CCI score, and baseline IADL score, only PPOs on geriatric rehabilitation discharge remained to be significantly associated with lower IADL score at 3-month post-discharge (incidence rate ratio = 0.868, 95% CI 0.776–0.972, $p = 0.014$).

Table 3 Association between potentially inappropriate medications (PIMs) or potential prescribing omissions (PPOs) and Activities of Daily Living (ADL) across three time points

	Model	ADL score					
		Geriatric rehabilitation admission		Geriatric rehabilitation discharge		3-month post-discharge	
		Incidence rate ratio (95% CI)	*p* value	Incidence rate ratio (95% CI)	*p* value	Incidence rate ratio (95% CI)	*p* value
PIMs (number of)							
Acute admission	Crude	1.006 (0.893–1.134)	0.919	1.039 (0.951–1.135)	0.397	0.941 (0.853–1.038)	0.225
	Model 1	1.008 (0.896–1.139)	0.810	1.042 (0.953–1.140)	0.364	0.937 (0.849–1.035)	0.201
	Model 2	1.025 (0.907–1.156)	0.712	1.052 (0.961–1.151)	0.273	0.947 (0.857–1.048)	0.293
Geriatric rehabilitation admission	Crude	N/A		0.968 (0.890–1.053)	0.453	0.963 (0.876–1.059)	0.437
	Model 1	N/A		0.973 (0.896–1.062)	0.535	0.961 (0.873–1.063)	0.444
	Model 2	N/A		1.001 (0.919–1.090)	0.980	0.992 (0.900–1.093)	0.864
Geriatric rehabilitation discharge	Crude	N/A		N/A		0.947 (0.862–1.039)	0.251
	Model 1	N/A		N/A		0.946 (0.861–1.039)	0.244
	Model 2	N/A		N/A		0.980 (0.891–1.079)	0.683
PPOs (number of)							
Acute admission	Crude	0.892 (0.791–1.006)	0.063	0.982 (0.897–1.075)	0.694	0.920 (0.833–1.016)	0.099
	Model 1	0.905 (0.802–1.021)	0.103	1.003 (0.916–1.099)	0.941	0.932 (0.843–1.030)	0.168
	Model 2	0.905 (0.801–1.021)	0.106	1.006 (0.918–1.103)	0.900	0.945 (0.854–1.046)	0.275
Geriatric rehabilitation admission	Crude	N/A		0.976 (0.889–1.072)	0.616	0.914 (0.825–1.012)	0.083
	Model 1	N/A		0.998 (0.908–1.097)	0.968	0.935 (0.844–1.037)	0.205
	Model 2	N/A		1.001 (0.911–1.105)	0.971	0.958 (0.864–1.063)	0.419
Geriatric rehabilitation discharge	Crude	N/A		N/A		0.913 (0.831–1.014)	0.089
	Model 1	N/A		N/A		0.933 (0.844–1.031)	0.171
	Model 2	N/A		N/A		0.950 (0.859–1.050)	0.314

Model 1: adjusted for age, sex and Charlson Comorbidity Index. Model 2: adjusted for age, sex, Charlson Comorbidity Index and baseline ADL score 2-week prior to hospitalization

PIMs potentially inappropriate medications, *PPOs* potential prescribing omissions, *ADL* activities of daily living, *N/A* not applicable

The associations between PIMs and PPOs use at admission to geriatric rehabilitation with the longitudinal changes of ADLs and IADLs from geriatric rehabilitation admission to 3-month post-discharge are shown in Table 5. There was no significant association between PIMs and PPOs use with ADLs (PIM: B = − 0.028, 95% CI − 1.887 to 1.832; PPO: B = − 0.025, 95% CI − 2.108 to 2.058) and IADLs (PIM: B = − 0.06, 95% CI − 0.267 to 0.147; PPO: B = − 0.746, 95% CI − 6.32 to 4.829) changes from geriatric rehabilitation admission to 3-month post-discharge.

Table 6 shows the associations between PIMs and PPOs at discharge from geriatric rehabilitation and ADLs and IADLs at 3-month post-discharge. Patients with renal PIMs were associated with higher IADL scores at the 3-month post-discharge (incidence rate ratio = 1.750, 95% CI 1.238–2.474, $p = 0.002$). Vaccine PPOs were associated with a lower IADL at the 3-month post-discharge (incident risk ratio = 0.844, 95% CI 0.754–0.944, $p = 0.003$).

Discussion

PIMs and PPOs were highly prevalent in geriatric rehabilitation patients. PIMs and PPOs were not associated with ADL scores at any stage from acute admission to geriatric rehabilitation admission, geriatric rehabilitation discharge, or at 3-month post-discharge. PIMs on acute admission were associated with higher IADL scores on geriatric rehabilitation discharge. PPOs on geriatric rehabilitation discharge were associated with lower IADL scores at 3-month post-discharge. Only renal PIMs were associated with higher IADL scores at 3-month post-discharge. PPOs involving vaccinations were associated with lower IADL scores at 3-month post-discharge. Trajectory analyses examining the changes in functional status during the geriatric rehabilitation stay and after the discharge as a function of changes in PIMs/PPOs showed no significant associations between PIMs and PPOs use with ADL and IADL changes from geriatric rehabilitation admission to 3-month post-discharge.

Table 4 Association between potentially inappropriate medications (PIMs) or potential prescribing omissions (PPOs) and instrumental activities of daily living (IADL) across three time points

	Model	IADL score					
		Geriatric rehabilitation admission		Geriatric rehabilitation discharge		3-month post-discharge	
		Incidence rate ratio (95% CI)	*p* value	Incidence rate ratio (95% CI)	*p* value	Incidence rate ratio (95% CI)	*p* value
PIMs							
Acute admission	Crude	1.033 (0.877–1.218)	0.696	1.142 (1.030–1.267)	**0.012**	0.953 (0.852–1.065)	0.394
	Model 1	1.017 (0.861–1.201)	0.845	1.139 (1.026–1.265)	**0.014**	0.931 (0.832–1.043)	0.216
	Model 2	1.040 (0.880–1.228)	0.648	1.165 (1.048–1.294)	**0.005**	0.981 (0.875–1.100)	0.745
Geriatric rehabilitation admission	Crude	NA		0.980 (0.890–1.080)	0.685	0.901 (0.809–1.004)	0.058
	Model 1	NA		0.990 (0.898–1.093)	0.823	0.909 (0.816–1.013)	0.083
	Model 2	NA		1.037 (0.940–1.144)	0.468	1.027 (0.920–1.147)	0.637
Geriatric rehabilitation discharge	Crude	NA		NA		0.886 (0.797–0.985)	**0.025**
	Model 1	NA		NA		0.877 (0.788–0.976)	**0.016**
	Model 2	NA		NA		0.991 (0.892–1.118)	0.940
PPOs							
Acute admission	Crude	0.859 (0.729–1.011)	0.068	1.028 (0.926–1.142)	0.603	0.827 (0.740–0.924)	**0.001**
	Model 1	0.876 (0.743–1.031)	0.112	1.056 (0.950–1.173)	0.311	0.849 (0.759–0.950)	**0.004**
	Model 2	0.890 (0.755–1.049)	0.164	1.068 (0.958–1.184)	0.250	0.901 (0.804–1.009)	0.072
Geriatric rehabilitation admission	Crude	NA		1.008 (0.905–1.124)	0.883	0.826 (0.738–0.926)	**0.001**
	Model 1	NA		1.041 (0.931–1.160)	0.502	0.874 (0.779–0.980)	**0.022**
	Model 2	NA		1.034 (0.926–1.154)	0.556	0.937 (0.833–1.053)	0.272
Geriatric rehabilitation discharge	Crude	NA		NA		0.789 (0.707–0.881)	**< 0.001**
	Model 1	NA		NA		0.815 (0.730–0.911)	**< 0.001**
	Model 2	NA		NA		0.868 (0.776–0.972)	**0.014**

Boldness of *p* values indicate results for $p < 0.05$

Model 1: adjusted for age, sex and Charlson Comorbidity Index. Model 2: adjusted for age, sex, Charlson Comorbidity Index and baseline IADL score 2-week prior to hospitalization

PIM potentially inappropriate medications, *PPO* potential prescribing omissions, *IADL* instrumental activities of daily living, *NA* not applicable

Associations between potentially inappropriate medications or potential prescribing omissions and activities of daily living

No significant associations were found between the use of PIMs and the ADL score at any of the time points of care or the 3-month post-discharge. Similarly, trajectory analyses showed no significant associations between PIMs and PPOs use with ADL changes from geriatric rehabilitation admission to 3-month post-discharge. While in this study ADL outcome was considered a continuous variable in the form of count data, other studies have tended to use ADLs as a binary outcome variable where diverse decisions were made about the categorical characteristics. Moriarty et al. assessed ADLs by interviewing participants about whether they had difficulties or not, in completing six named ADLs [19]. The outcome variable used was binary, which related to participants' reported difficulties with each ADL between baseline assessment and follow-up. In the work by Corsonello et al., they examined ADLs as an outcome variable by considering the loss of one or more ADLs and loss of three or more ADLs from admission to discharge from hospital [20]. In Tosato et al.'s work, they assessed patients' competency in six activities comprising bathing, locomotion, dressing, eating, bowel and bladder continence, and personal hygiene [21]. They developed a summated score between 0 and 6, relating to the number of ADLs for which patients were dependent at hospital admission and at discharge. Subsequently, they calculated a change in the ADL score and determine decline in functional status as an increment of one or more points in the score between admission and discharge. In these studies involving binary outcome variables for ADLs, mixed results were obtained for the effects of inappropriate medications on ADLs. Furthermore, when an ADL score was considered as a continuous outcome variable, inappropriate anticholinergic use was significantly associated with lower ADL scores [22]. In view of the diverse

Table 5 Association between potentially inappropriate medications (PIMs) or potential prescribing omissions (PPOs) at admission to geriatric rehabilitation and the longitudinal changes in Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) from geriatric rehabilitation admission to 3-month post-discharge

	ADL score						IADL score					
	Crude model			Adjusted model			Crude model			Adjusted model		
	B	95% CI		*B*	95% CI		*B*	95% CI		*B*	95% CI	
		Lower bound	Upper bound		Lower bound	Upper bound		Lower bound	Upper bound		Lower bound	Upper bound
PIM	− 0.040	− 2.048	1.968	− 0.028	− 1.887	1.832	0.329	− 0.451	1.109	− 0.060	− 0.267	0.147
PPO	− 0.029	− 2.275	2.216	− 0.025	− 2.108	2.058	0.421	− 0.096	0.939	− 0.746	− 6.320	4.829

Adjusted for age, sex and Charlson Comorbidity Index

PIM potentially inappropriate medications, *PPO* potential prescribing omissions, *ADL* activities of daily living, *IADL* instrumental activities of daily living, *B* beta regression coefficient, *CI* confidence interval

depictions of categories for ADL as a binary outcome variable, greater consistency of results may be achieved using ADL as a continuous outcome variable.

ADLs consist of basic tasks needed to live independently at home, and impairment of ADLs is often caused by diseases [23]. In the current study, although the patients were prescribed PIMs, their undesirable effects may not had been sufficient to cause impairment of independence in basic physical tasks at the 3-month period.

Previous work has shown a lack of association between PPOs and ADL scores [24, 25] Nevertheless, one longitudinal study identified that PPOs were associated with a decline in ADL scores at 12-month post-discharge if patients had two or more PPOs [19]. The lack of association between PPOs and ADL scores could be attributed to 3 months not being a long enough time period to identify changes in basic skills for independence.

Associations between potentially inappropriate medications or potential prescribing omissions and instrumental activities of daily living

PIMs were associated with increased IADL scores at geriatric rehabilitation discharge while PPOs were associated with lower IADL scores at 3-month post-discharge. Conversely, trajectory analysis showed no significant associations between PIMs and PPOs use with IADL changes from geriatric rehabilitation admission to 3-month post-discharge. Differences between single time point and trajectory analyses existed probably because trajectory analyses took into account the IADL functioning at baseline. The question remains as to why PIMs and PPOs were associated with IADL scores but not ADL scores in single time point analyses. IADLs and ADLs have a hierarchical relationship, requiring different physical attributes by older patients [26]. IADLs require cognitive and emotional capacity as well as physical functioning for successful performance [27], whereas ADLs are more dependent on physical functioning. Therefore, the association between inappropriate medication and IADL scores could be affected by factors other than only physical activity. Further research needs to be undertaken to examine how PIMs and PPOs cause variations in ADL and IADL function.

Patients prescribed PIMs relating to the renal system showed higher IADL scores at 3-month post-discharge. Medications in the renal criterion comprise digoxin, non-steroidal anti-inflammatory drugs, and metformin [7]. It is possible that while consuming these medications, patients may have been in a better position to complete complex domestic activities due to improved cardiac function, reduced levels of pain or optimal levels of blood glucose. For these patients, it is possible that the therapeutic benefits observed, may have outweighed possible adverse effects related to these

Table 6 Association between potentially inappropriate medications (PIMs) and potential prescribing omissions (PPOs) at discharge from geriatric rehabilitation and activities of daily living and instrumental activities of daily living at 3-month post-discharge, stratified by PIM and PPO section

Section	Patients with ≥ 1 PIM/PPO, *n* (%)	ADL 3-month post-discharge		IADL 3-month post-discharge	
		Incidence rate ratio (95% CI)	*p* value	Incidence rate ratio (95% CI)	*p* value
PIMs					
A (indication of medication)	274 (39.5)	1.002 (0.909–1.106)	0.962	1.062 (0.950–1.186)	0.290
B (cardiovascular)	66 (9.5)	1.052 (0.893–1.241)	0.544	1.069 (0.880–1.299)	0.502
C (antiplatelet/anticoagulant)	18 (2.6)	0.880 (0.610–1.271)	0.497	1.119 (0.752–1.663)	0.580
D (central nervous and psychotropics)	37 (5.3)	1.009 (0.814–1.252)	0.934	1.109 (0.862–1.427)	0.423
E (renal)	9 (1.3)	1.124 (0.811–1.559)	0.482	1.750 (1.238–2.474)	**0.002**
F (gastrointestinal)	43 (6.2)	0.927 (0.735–1.170)	0.523	1.081 (0.842–1.387)	0.541
G (respiratory)	0	N/A		N/A	
H (musculoskeletal)	7 (1.0)	1.012 (0.675–1.516)	0.954	0.891 (0.558–1.421)	0.628
I (urogenital)	1 (0.1)	1.345 (0.558–3.246)	0.509	0.468 (0.066–3.332)	0.448
J (endocrine)	2 (0.3)	1.082 (0.449–2.608)	0.861	0.258 (0.036–1.837)	0.176
K (falls risk)	100 (14.4)	0.893 (0.772–1.033)	0.129	0.886 (0.748–1.050)	0.163
L (analgesics)	62 (8.9)	1.004 (0.832–1.211)	0.967	0.929 (0.744–1.162)	0.520
M (antimuscarinics/anticholinergic)	0	N/A		N/A	
PPOs					
A (cardiovascular)	195 (28.1)	0.988 (0.883–1.106)	0.835	0.961 (0.843–1.096)	0.555
B (respiratory)	21 (3.0)	0.985 (0.742–1.308)	0.916	0.962 (0.685–1.351)	0.825
C (central nervous)	21 (3.0)	0.861 (0.658–1.127)	0.277	0.801 (0.557–1.153)	0.233
D (gastrointestinal)	5 (0.7)	1.182 (0.774–1.804)	0.439	1.469 (0.943–2.289)	0.089
E (musculoskeletal)	163 (23.5)	1.005 (0.899–1.123)	0.934	0.975 (0.859–1.107)	0.700
F (endocrine)	24 (3.5)	0.980 (0.711–1.351)	0.902	1.200 (0.835–1.726)	0.325
G (urogenital)	7 (1.0)	0.847 (0.478–1.500)	0.569	0.975 (0.520–1.826)	0.936
H (analgesics)	29 (4.2)	1.054 (0.816–1.362)	0.688	0.974 (0.725–1.308)	0.860
I (vaccines)	318 (45.9)	0.950 (0.862–1.046)	0.293	0.844 (0.754–0.944)	**0.003**

Boldness of *p* values indicate results for $p < 0.05$

Adjusted for age, sex, Charlson Comorbidity Index and baseline ADL/IADL score 2-week prior to hospitalization

ADL activities of daily living, *IADL* instrumental activities of daily living, *N/A* not applicable as no patients were prescribed this PIM

medications. PIMs affecting the renal system may have also contributed to the significantly increased IADL scores at geriatric rehabilitation discharge. It is also important to note that the number of older patients prescribed renal PIMs at 3 months was relatively low. The study also showed that PPOs comprising vaccinations were associated with lower IADL scores at the 3-month post-discharge. The results also identified that the presence of vaccine PPOs was associated with a lowered IADL at the 3-month post-discharge. It is possible that lack of administration of the seasonal influenza vaccine and the pneumococcal vaccine that comprise the vaccine PPOs [7], may had actually led to influenza and pneumococcal infections that impeded patients' function.

Implications of study findings

Greater attention is needed in reducing PPOs in geriatric rehabilitation inpatients that can potentially impact IADLs. Similarly, in the community, health professionals such as general practitioners, general practice nurses, physiotherapists and occupational therapists need to be vigilant about assessing how older patients' physical functioning may be affected by inappropriate medication prescribing.

Limitations

The study was undertaken at one tertiary, metropolitan hospital and the results cannot be generalizable to other hospitals. In addition, the PIMs and PPOs identified from the STOPP and START criteria were 'potentially' inappropriate. There was no formal assessment made to determine whether these PIMs or PPOs were actually inappropriate.

Conclusion

PPOs were associated with lowered IADL scores at 3-month post-discharge. Health professionals need to take care in reducing PPOs at hospital discharge, as it is possible that inappropriate medication use may lead to problems with older patients' physical function.

Acknowledgements The authors thank the multidisciplinary team members of the Royal Melbourne Hospital, Royal Park Campus, involved in the RESORT study for their clinical work and the @Age-Melbourne team for their role in the data collection.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by EM, CHS, MZK, EMR, and ABM. The first draft of the manuscript was written by EM and all authors reviewed and revised the manuscript. All authors read and approved the final manuscript.

Funding Medical Research Future Fund provided by the Melbourne Academic Center of Health.

Data availability Any queries about data and material should be directed to the last author.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Melbourne Health Human Research Ethics Committee, HREC/17/MH/103) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to participate All participants or their nominated proxies provided written informed consent.

Consent for publication Not applicable.

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