

Supplementary material

Title: Development and validation of a machine learning-based fall-related injury risk prediction model using nationwide claims database in Korean community-dwelling older population

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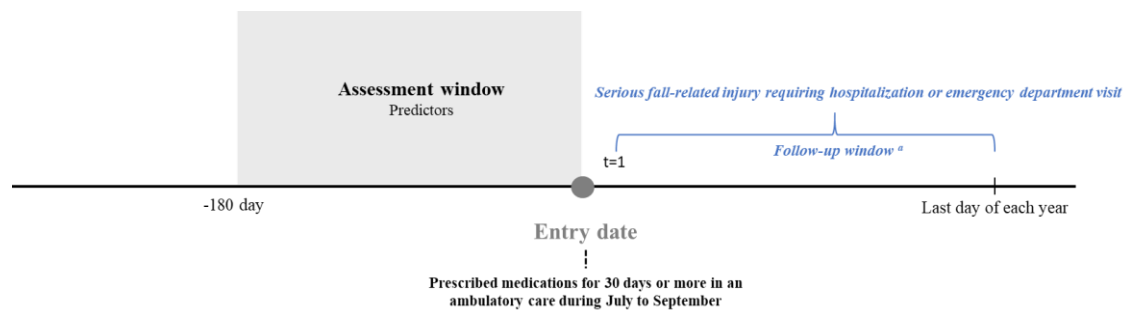


Figure S1. Graphical depiction of entry date, assessment window, and follow-up

^a Earliest of: fall-related injury, death, the last day of the each year

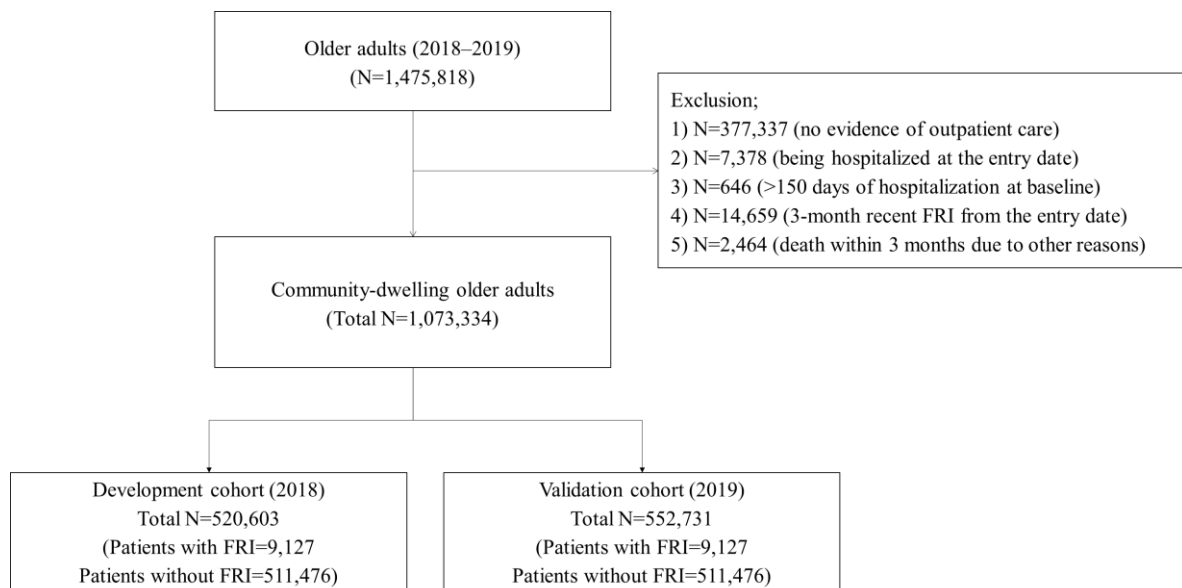


Figure S2. Patient selection flow

FRI, fall-related injury

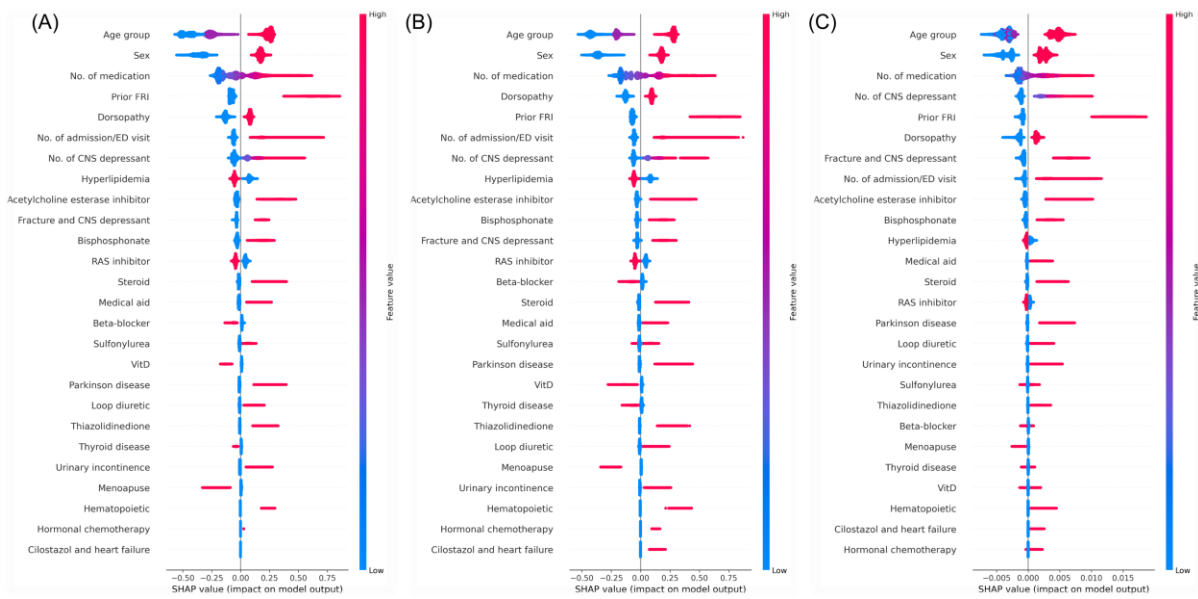


Figure S3. SHAP summary plot for LightGBM, XGBoost and Random Forest

FRI, fall-related injury; CNS, central nervous system; ED, emergency department

(A): LightGBM

(B): XGBoost

(C): Random Forest

Table S1. Diagnostic codes to identify fall-related injuries

Falls-and fall-related injury	ICD-10 code
Fall	W00~W19*
Fracture	S02, S12, S22, S32, S42, S52, S620, S621, S72, S82, S920, T02*, T08*, T10*, T12*, T142*
Head injury	S06, S07
Dislocation	S131, S132, S133, S231, S232, S331, S332, S333, S430, S431, S432, S433, S530, S531, S730, S830, S831

*The diagnostic codes were masked in the raw data. ICD-10, International Classification of Diseases, Tenth Revision;

Table S2. Summary of candidate features (n=186)

Demographics	Healthcare utilization	Disease	Medication		Drug-Drug interaction	Drug-disease interaction
- Sex - Age group - Medical aid	- Baseline hospitalization period - No. of admission or ED visit - No. of admission - No. of ED visit	- CCI score - Prior fall-related injury - Pathologic fracture - Ischemic heart disease - Myocardial infarction - Chronic heart failure - Cerebrovascular disease - Ischemic stroke - Intracranial hemorrhage - Peripheral vascular disease - Thromboembolism - Hypertension - Arrhythmia - Atrial fibrillation - Bradycardia, atrioventricular block - Syncope, hypotension - Diabetes mellitus - Type 1 Diabetes mellitus - Type 2 Diabetes mellitus - Hyperlipidemia - Arthropathy - Dorsopathy - Soft tissue disease - Ankylosing spondylitis - Rheumatic arthritis - Osteoarthritis - Osteoporosis - Vertigo - Dizziness - Renal disease - Liver disease - Cancer - Parkinson disease - Anemia - Hyponatremia - Hypokalemia - Paralysis - Glaucoma - Gout - Menopause - Thyroid disease - Hyperthyroidism - Hypothyroidism - Major bleeding - Asthma - COPD - BPH - Urinary retention - Urinary incontinence - Peptic ulcer disease - Insomnia - Obesity	- No. of medication - No. of CNS depressants - No. of fall-risk increasing drugs - Opioid - No. of opioid - Tramadol - Weak opioid - Strong opioid - Benzodiazepines - No. of benzodiazepines - Benzodiazepines (short acting) - Benzodiazepines (long acting) - Zolpidem - Gabapentinoids - Antiepileptics - No. of antiepileptics - Antipsychotics - Typical antipsychotics - Atypical antipsychotics - Lithium - Antidepressants - No. of antidepressants - TCA - SSRI - SNRI - Antihypertensives - No. of antihypertensives - Vasodilators - Diuretics - No. of diuretics - Loop diuretics - Beta blockers - CCB - DHP CCB - NDHP CCB - ACEi/ARB - Alpha blockers - Antianthymics - Antianthymics (class 1b) - Antianthymics (class 1c) - Antianthymics (class 3) - digoxin - Dopaminergic agents - Traditional NSAIDs - Cox-2 inhibitor - Strong anticholinergic agents - No. of strong anticholinergic agents 1st generation antihistamines	- Antidiabetic agents - No. of antidiabetic agents - Metformin - Sulfonylurea - SGLT2 inhibitors - Thiazolidinedione - DPP-4 inhibitor - Meglitinide - Alpha glucosidase inhibitor - GLP-1 receptor agonist - Insulin - Insulin (short acting) - Insulin (long acting) - Insulin (premixed) - Proton pump inhibitor - Steroid - Osteoporosis treatment - Calcium - Vitamin D - Bisphosphonate - Tibolone, raloxifene and bazedoxifene - Anticoagulants - Warfarin - DOAC - LMWH - Antiplatelet agents - No. of antiplatelet agents - P2Y12 inhibitor - Low dose aspirin - Other antiplatelet - Anti-anemic preparations (oral) - Iron - VitB12 - Folic acid - Erythropoiesis-stimulating agents - Acetylcholine esterase inhibitor - Antispasmodic - Muscle relaxant - Thyroid hormones - Antithyroid - Inhaled steroids - Chemotherapy - Hormonal chemotherapy - Anti-estrogens - Aromatase inhibitor - Antiandrogen - Sex hormones - Megestrol - Metoclopramide - Desmopressin	- ACEi/ARB & potassium sparing diuretics - Opioid & Gabapentinoids - Opioid & Benzodiazepines - Lithium & ACEi/ARB - Theophylline & Cimetidine - Theophylline & Ciprofloxacin - Warfarin & Amiodarone - Warfarin & NSAIDs - Beta blocker & NDHP CCB - Acetylcholine esterase inhibitor & Beta blockers/digoxin/NDHP CCB ≥2 strong anticholinergic agents ≥3 CNS depressants ≥2 Benzodiazepines ≥2 Traditional NSAIDs ≥2 SSRIs ≥2 loop diuretics ≥2 anticoagulants ≥2 antiplatelets	- Heart failure & NDHP CCB - Heart failure & NSAIDs - Heart failure & thiazolidinedione - Heart failure & cilostazol - Heart failure & dronedarone - Syncope & Acetylcholine esterase inhibitor - Fracture & CNS depressants - Parkinson disease & antipsychotics - Peptic ulcer disease & traditional NSAIDs - CKD & traditional NSAIDs - Bradycardia & beta blockers - Bradycardia & acetylcholine esterase inhibitor

ED, emergency department; CCI, Charlson comorbidity index; COPD, chronic obstructive pulmonary disease; BPH, benign prostatic hyperplasia; CNS, central nervous system; TCA, tricyclic antidepressants; SSRI, selective serotonin reuptake inhibitor; SNRI, serotonin-norepinephrine reuptake inhibitor; CCB, calcium channel blocker; DHP, dihydropyridine; NDHP, non-dihydropyridine; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; NSAIDs, non-steroidal anti-inflammatory drugs; SGLT2, sodium-glucose cotransporter-2; DPP-4, dipeptidyl peptidase-4; GLP-1, glucagon-like peptide 1; DOAC, direct oral anticoagulant; LMWH, low molecular weight heparin; P2Y12; CKD, chronic kidney disease

Table S3. Explored parameter fields and selected parameters

Model	Hyperparameter	Parameter space	Selected parameters
LightGBM	boosting_type	goss	“goss”
	n_estimators	[100, 640]	580
	learning_rate	[0.001, 0.3]	0.5564
	num_leaves	[20, 500]	380
	max_depth	[3, 12]	11
	min_data_in_leaf	[50, 10000]	50
	lambda_l1	[0, 100]	10
	lambda_l2	[0, 100]	55
	min_gain_to_split	[0, 15]	5.8008
CatBoost	feature_fraction	[0.2, 1]	0.5
	depth	[3, 12]	6
	learning_rate	[0.001, 0.3]	0.0168
	iterations	[10, 1000]	760
	colsample_bylevel	[0.2, 1.0]	0.4555
	min_data_in_leaf	[100, 10000]	8224
	l2_leaf_reg	[0.0001, 100]	84.0688
XGBoost	subsample	[0.2, 1.0]	0.6412
	tree_method	Gpu_hist	Gpu_hist
	booster	Gbtree	Gbtree
	max_depth	[3, 32]	3
	learning_rate	[0.001, 0.3]	0.0365
	n_estimators	[50, 1000]	784
	min_child_weight	[1, 1000]	16
	gamma	[0.0001, 1.0]	0.0035
	alpha	[0.0001, 10.0]	0.0911
	lambda	[0.0001, 10.0]	0.0002
	colsample_bytree	[0.2, 1.0]	0.4442
	colsample_bylevel	[0.2, 1.0]	0.3681
	subsample	[0.2, 1.0]	0.6472
Random Forest	bootstrap	True	True
	n_estimators	[100, 1000]	511
	max_features	[3, 26]	3
	max_depth	[3, 50]	12
	min_samples_split	[10, 10000]	1236
	min_samples_leaf	[10, 10000]	82

Table S4. Association between selected features and fall-related injury

Risk factor	Univariable OR (95% CI)	p-value	Multivariable aOR (95% CI)	p-value
Age group				
65~69	Reference		Reference	
70~74	1.36 (1.28-1.46)	<.001	1.24 (1.16-1.33)	<.001
≥75	2.54 (2.40-2.68)	<.001	1.99 (1.87-2.1)	<.001
Female	2.00 (1.91-2.10)	<.001	1.74 (1.66-1.83)	<.001
Medical aid	1.57 (1.47-1.68)	<.001	1.13 (1.06-1.21)	<.001
No. of admission/ED visit	1.35 (1.31-1.38)	<.001	1.18 (1.14-1.21)	<.001
Prior fall-related injury	2.89 (2.72-3.06)	<.001	1.97 (1.85-2.11)	<.001
Hyperlipidemia	0.96 (0.92-1.00)	0.055	0.86 (0.82-0.9)	<.001
Dorsopathy	1.65 (1.58-1.72)	<.001	1.24 (1.18-1.3)	<.001
Parkinson disease	2.07 (1.87-2.29)	<.001	1.27 (1.15-1.42)	<.001
Menopause	0.81 (0.70-0.95)	0.009	0.74 (0.63-0.87)	<.001
Thyroid disease	1.12 (1.05-1.19)	<.001	0.94 (0.88-1)	0.054
Urinary incontinence	1.71 (1.54-1.89)	<.001	1.16 (1.05-1.29)	0.005
Medication factors				
No. of medication	1.08 (1.07-1.08)	<.001	1.04 (1.03-1.05)	<.001
No. of CNS depressant	1.29 (1.27-1.31)	<.001	1.06 (1.04-1.08)	<.001
Loop diuretic	1.60 (1.48-1.74)	<.001	1.13 (1.03-1.23)	0.007
Beta-blocker	1.08 (1.02-1.14)	0.009	0.91 (0.85-0.96)	<.001
ACEi/ARB	0.93 (0.89-0.97)	<.001	0.90 (0.86-0.94)	<.001
Sulfonylurea	1.09 (1.03-1.16)	0.006	1.07 (1.01-1.15)	0.036
Thiazolidinedione	1.27 (1.13-1.43)	<.001	1.32 (1.16-1.49)	<.001
Steroid	1.67 (1.54-1.82)	<.001	1.31 (1.2-1.43)	<.001
Vitamin D	1.33 (1.21-1.45)	<.001	0.82 (0.74-0.91)	<.001
Bisphosphonate	1.77 (1.67-1.87)	<.001	1.23 (1.15-1.31)	<.001
Acetylcholine esterase inhibitor	2.22 (2.09-2.37)	<.001	1.34 (1.25-1.43)	<.001
Hormonal chemotherapy	1.10 (0.84-1.43)	0.5	1.13 (0.87-1.48)	0.361
Hematopoietic drugs	1.80 (1.47-2.20)	<.001	1.40 (1.14-1.72)	0.001
Drug-disease interaction				
Heart failure and cilostazol	1.59 (1.24-2.04)	<.001	1.13 (0.88-1.45)	0.352
Fracture and CNS depressant	2.37 (2.25-2.50)	<.001	1.21 (1.13-1.29)	<.001

OR, odds ratio; aOR, adjusted odds ratio; CI, confidence interval; ED, emergency department; CNS, central nervous system; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker