Am J Transl Res 2026;18(8):7189-7200
www.ajtr.org /ISSN:1943-8141/AJTR0174288

Original Article

Risk factors and a predictive nomogram for in-hospital deep vein thrombosis in elderly patients with multiple chronic conditions

Ying Luo, Manyu Xu, Zhiying Xu, Hongmei Ji, Yalei Wu, Huan Shen, Caifeng Guan

Geriatrics Department, Suzhou Ninth People's Hospital, Suzhou 215200, Jiangsu, China

Received May 26, 2026; Accepted July 9, 2026; Epub August 15, 2026; Published August 30, 2026

Abstract: Objective: To explore the independent influencing factors of deep venous thrombosis (DVT) in elderly patients with multiple chronic conditions (MCCs) and construct a predictive nomogram for this population. Methods: A total of 689 elderly patients with MCCs who were hospitalized from January 2023 to March 2025 were retrospectively enrolled in this study. Patients were categorized into a DVT group (73 cases) and a non-DVT group (616 cases). The overall cohort was randomly split into a training set (482 cases) and an internal validation set (207 cases) at a 7:3 ratio. An additional 360 patients admitted from April 2025 to April 2026 were enrolled as an external validation cohort. Receiver operating characteristic (ROC) curves, calibration curves, and decision curve analysis (DCA) were used to evaluate the performance of the predictive model. Results: Age, MCCs number, polypharmacy, Padua score, limb muscle strength and DPR were identified as independent predicting factors for in-hospital DVT. The nomogram achieved an area under the curve (AUC) of 0.848. The AUC was 0.846 for the training set and 0.831 for the internal validation set, with good calibration. The external validation AUC was 0.807 with satisfactory calibration efficiency, and the DeLong test verified no significant difference in AUC values ($P > 0.05$). Furthermore, the model presented favorable clinical net benefits. Conclusion: The validated nomogram established based on six routinely accessible clinical indicators can effectively and reliably predict the risk of in-hospital DVT in elderly patients with MCCs.

Keywords: Aged, multiple chronic conditions, limb muscle strength, deep vein thrombosis, influencing factors, nomogram model

Introduction

Chronic disease multimorbidity, also defined as multiple chronic conditions (MCCs), refers to the coexistence of two or more chronic diseases [1, 2] and is highly prevalent in the elderly population [3, 4]. Vascular aging progresses gradually with advanced age, leading to vascular intima damage and reduced blood flow. Concurrent chronic illnesses, including hypertension, hyperlipidemia, diabetes, coronary heart disease, cerebral infarction and malignancy, further aggravate vascular damage and elevate blood viscosity [5]. Additionally, interactions among multiple chronic disorders disrupt normal coagulation homeostasis, thereby predisposing patients to deep vein thrombosis (DVT) and increasing the risk of adverse clinical outcomes [6]. Existing studies have confirmed that dislodged thrombus fragments can travel through the bloodstream and occlude major organ arteries or their branches, resulting in irreversible organ dysfunction [7]. Clinicians currently rely on traditional risk stratification scales (such as the Padua and Wells scores) to assess in-hospital thrombotic risk at admission and implement targeted thromboprophylaxis. Nevertheless, clinical observations indicate that numerous elderly patients still develop DVT-related manifestations during hospitalization, including unilateral limb swelling, edema, pain, skin pigmentation, and cutaneous degeneration. This limitation may occur because conventional thrombotic risk scales fail to fully incorporate unique geriatric risk factors, such as multimorbidity burden, polypharmacy and limb mobility dysfunction, thereby resulting in inaccurate risk stratification and suboptimal preventive interventions. Predictive models based on comprehensive clinical data

https://doi.org/10.62347/GFEV3120

can identify independent risk factors for in-hospital DVT in elderly patients with multimorbidity and facilitate the development of a tailored nomogram model, which support individualized DVT risk screening and prevention strategies.

Material and methods

Research subjects

We retrospectively collected data from 689 older adults with MCCs admitted to the Department of Geriatrics, Suzhou Ninth People's Hospital from January 2023 to March 2025. Patients were divided into a DVT group (73 cases) and a non-DVT group (616 cases) according to the presence of DVT during hospitalization. An independent cohort comprising 360 older inpatients with MCCs who were admitted to the same department between April 2025 and April 2026 was subsequently included for external validation of the predictive model.

Inclusion criteria: (1) Age ≥ 60 years old; (2) Suffering from two or more chronic diseases at the same time (such as hypertension, diabetes, hyperlipidemia, cardiovascular and cerebrovascular diseases, osteoarthritis, cancer); (3) The patient underwent limb muscle strength testing upon admission.

Exclusion criteria: (1) Individuals diagnosed with venous thrombotic disease upon admission; (2) Critical illness patients with unstable vital signs upon admission and requiring continuous monitoring; (3) Patients with incomplete clinical data; (4) Individuals who are unable to take care of themselves due to physical, intellectual, or mental conditions and require long-term care from others; (5) Those who have not undergone color Doppler ultrasound examination during hospitalization.

This study has been approved by the Medical Ethics Committee of Suzhou Ninth People's Hospital (KYLW2025-026-01).

Research methods

Clinical information: By reviewing the patient's electronic medical records, clinical information of the patient upon admission was obtained, including age, gender, body mass index (BMI), smoking history, alcohol consumption history, number of MCCs, polypharmacy (defined as the concurrent use of two or more medications, including prescription drugs, over-the-counter drugs, and herbal supplements).

Blood indicators: By reviewing the patient's blood test report at the time of admission, the patient's blood indicators were obtained, mainly including albumin, platelets, fasting blood glucose, triglycerides, activated partial thromboplastin time, prothrombin time, fibrinogen and D-dimer. Based on the platelet count and D-dimer indicators, the D-dimer/platelet ratio (DPR) was calculated.

Assessment of limb muscle strength: Limb muscle strength was assessed at admission using the Medical Research Council (MRC) grading system. Patients were examined in the supine position, and muscle strength was evaluated by active movement against gravity and external resistance. Muscle strength was graded from 0 to 5: grade 0, no muscle contraction; grade 1, slight contraction without joint movement; grade 2, movement with gravity eliminated; grade 3, movement against gravity but not resistance; grade 4, movement against gravity and moderate resistance; and grade 5, normal muscle strength. The average MRC score of the upper and lower extremities was calculated as the final muscle strength index, with higher scores indicating greater limb muscle strength [8].

Padua rating: Within 24 hours of admission, venous thromboembolism (VTE) risk was assessed using the Padua Score. The score comprises 11 risk factors, including active cancer (3 points), previous VTE (3 points), reduced activity ≥ 3 days (3 points), tendency to form blood clots (3 points), recent trauma or surgery (2 points), age ≥ 70 years (1 point), respiratory and/or heart failure (1 point), acute infection and/or rheumatic disease (1 point), acute myocardial infarction and/or ischemic stroke (1 point), BMI ≥ 30 kg/m^2 (1 point), and ongoing hormone therapy (1 point). Higher total scores indicates a greater risk of DVT [9].

DVT diagnosis: Referring to the relevant diagnostic criteria in the guidelines for the diagnosis and treatment of deep vein thrombosis [10]. DVT was diagnosed in patients with MCCs who either developed clinical symptoms (e.g., localized pain, swelling, skin cyanosis) during hospi-

talization, or were asymptomatic but had positive findings on Doppler ultrasound. DVT was diagnosed if any one of the following criteria were met: ① Incomplete venous compressibility: When transverse compression is applied with the ultrasound probe, the lumen of a normal vein fully collapses with apposition of the venous walls. In the presence of thrombus, the venous lumen cannot be compressed flat; ② Intraluminal solid echo filling: Solid hypoechoic or isoechoic material is visualized within the venous lumen, with no normal anechoic blood space remaining; ③ Marked venous luminal dilatation: The diameter of the affected venous segment is ≥ 1.5 times that of the accompanying ipsilateral artery, presenting as vascular distension; ④ Absent or intermittent faint blood flow signals: No transmitted blood flow passes through the affected vessel even after distal calf compression or Valsalva maneuver.

Statistical methods

SPSS 27.0 software was used to analyze the data. The Shapiro Wilk test is used to determine the normality of the measurement data. Continuous variables following a normal distribution were presented as mean ± standard deviation and were compared using the independent-samples t-test. Non-normally distributed continuous variables are presented as median (interquartile range, IQR) and were compared using the Mann-Whitney U test. Categorical variables are presented as counts (percentages) and were compared using the chi-square (χ^2) test. Collinearity diagnosis was perfomed on variables with P < 0.1 between two groups, with variance inflation factor (VIF) values < 5 used to indicate that there is no significant collinearity between the variables. Variables without significant collinearity were then entered into a multivariable logistic regression model to identify independent risk factors for in-hospital DVT. The data obtained from the analysis of the influencing factors were imported into R software, and the "rms" package was run to establish a nomogram model. The area under the receiver operating characteristic (*ROC*) curve (*AUC*), calibration curve, and decision curve were used to evaluate the performance of the model. DeLong test was used to compare the difference of *AUC* values, $P < 0.05$ indicated that the difference was statistically significant.

Results

Comparison of data between the DVT group and non-DVT group

Significant differences were observed between the DVT and non-DVT groups in terms of age, number of MCCs, polypharmacy, Padua score at admission, limb muscle strength, D-dimer, and DPR ($P < 0.05$) (**Table 1**).

Collinearity diagnosis analysis

To minimize the influence of multicollinearity, collinearity diagnostics were performed for variables with $P < 0.1$ in the univariate analysis, which included age, smoking history, number of MCCs, polypharmacy, limb muscle strength, platelet count, fasting blood glucose, D-dimer, and DPR. The results revealed no significant multicollinearity (*VIF* < 5) for age, number of MCCs, polypharmacy, limb muscle strength and DPR. Significant multicollinearity (*VIF* > 5) was detected for smoking history, platelet count, fasting blood glucose, and D-dimer (**Table 2**).

Multivariate logistic regression analysis

Whether elderly MCCs patients experienced DVT during hospitalization (0= No, 1= Yes) was used as the dependent variable, and indicators were analyzed with $P < 0.05$ in **Table 1** as independent variables (input original values). The results of multiple logistic regression analysis showed that: Age, high number of MCCs, high polypharmacy, high Padua score and DPR at admission are all risk factors for DVT in elderly MCCs patients during hospitalization ($P < 0.05$), with limb muscle strength as its protective factor ($P < 0.05$) (**Table 3**).

Construction, interpretation and efficiency analysis of the nomogram model

Based on the results of multivariate logistic regression analysis, age, number of MCCs, polypharmacy, admission limb muscle strength, Padua score and DPR were selected as predictive indicators. The "rms" package in R software was used to construct and visualize the DVT risk prediction nomogram. Interpretation of the nomogram prediction model: For example, an elderly patient with MCCs aged 75 years, suffering from 5 chronic diseases, three

Table 1. Comparison of baseline data between DVT and non-DVT groups

Clinical data	DVT group (*n*=73)	Non-DVT group (*n*=616)	t/χ^2/*U*	*P*
Age (years)	73.95±5.89	72.54±4.68	2.363	0.018
BMI (kg/m^2)	22.82±3.67	22.69±3.15	0.327	0.744
Sex			0.160	0.689
Male	41 (56.16)	361 (61.85)		
Female	32 (43.84)	255 (38.15)		
Smoking history			3.147	0.076
Yes	27 (36.99)	167 (27.11)		
No	46 (63.01)	449 (72.89)		
Alcohol consumption history			2.409	0.121
Yes	24 (32.88)	151 (24.51)		
No	49 (67.12)	465 (75.49)		
Number of MCCs (types)	4.21±0.75	4.04±0.55	2.392	0.017
Polypharmacy (types)	3.49±0.67	3.35±0.42	2.498	0.013
Limb muscle strength (level)	3.58±0.54	3.86±0.68	3.393	0.001
Padua rating (points)	3.70±0.75	3.39±0.61	2.709	0.011
Albumin (g/L^{-1})	37.88±4.93	38.17±5.46	0.433	0.665
Platelet (×10^9/L^{-1})	245.9 (170.9-340.5)	236.1 (150.9-290.2)	2.193	0.072
Fasting blood glucose (mmol/L^{-1})	5.7 (4.4-10.1)	5.3 (4.2-9.6)	1.875	0.094
Triglyceride (mmol/L^{-1})	1.4 (1.1-2.9)	1.3 (1.0-2.7)	1.683	0.114
Activated partial thromboplastin time (s)	27.88±3.67	28.35±3.54	1.068	0.286
Prothrombin time (s)	12.16±3.56	12.05±1.28	0.532	0.595
Fibrinogen (g/L^{-1})	3.42±0.98	3.27±0.86	1.388	0.166
D-dimer (mg/L^{-1})	0.71±0.26	0.63±0.20	3.121	0.002
DPR (×10^{-2})	0.29±0.05	0.26±0.03	7.417	< 0.001

Note: BMI, Body mass index; MCCs, Multiple chronic conditions; DPR, D-dimer/platelet ratio.

Table 2. Collinearity analysis

Indicator	No-standardized coefficient		Standard coefficient *beta*	*t*	Significance	Collinearity statistics	
	b	*SE*				Allow	*VIF*
Age	0.182	0.038	0.121	4.789	0.026	0.059	2.481
Smoking history	0.126	0.043	0.137	2.930	0.049	0.042	5.189
MCCs	0.155	0.013	1.321	11.923	< 0.001	0.197	3.031
Polypharmacy	0.098	0.034	-0.176	2.882	0.011	0.074	2.352
Muscle strength of limbs	-0.186	0.013	0.145	-14.307	< 0.001	0.037	2.793
Padua rating	0.192	0.015	0.468	12.803	< 0.001	0.014	3.096
Platelet	-0.076	0.053	0.235	-1.434	0.075	0.019	5.859
Fasting blood glucose	0.035	0.002	0.128	17.502	< 0.001	0.103	5.064
D-dimer	0.039	0.025	0.145	2.176	0.042	0.037	5.178
DPR	0.235	0.054	0.254	4.352	0.037	0.054	3.768

Note: MCCs, Multiple chronic conditions; DPR, D-dimer/platelet ratio.

types of polypharmacy, limb muscle strength grade 3, Padua score of 5 and DPR of 0.36, the total score would be 221 (29+31+15+40+36+70), corresponding to an estimated DVT risk of approximately 60% (**Figure 1**). *ROC* curve analysis showed that the *AUC* of the nomogram model was 0.848, and the DeLong test showed that the *AUC* value of the nomogram model was better than that of the single predictor ($P < 0.05$) (**Figure 2**; **Table 4**).

Table 3. Multivariate logistic regression analysis of independent risk factors for in-hospital DVT

Variable	*β*	*SE*	Wald χ^2	*P*	*OR* (95% *CI*)
Age	0.692	0.287	5.814	0.016	1.998 (1.138-3.508)
Number of MCCs	0.875	0.348	6.322	0.012	2.399 (1.213-4.745)
Polypharmacy	0.956	0.354	7.293	0.007	2.601 (1.301-5.206)
Limb muscle strength	-1.248	0.352	12.570	< 0.001	0.287 (0.144-0.572)
Padua rating	0.585	0.276	4.493	0.034	1.795 (1.045-3.083)
DPR	1.029	0.347	8.794	0.003	2.798 (1.417-5.521)

Note: MCCs: Multiple chronic conditions; DPR: D-dimer/platelet ratio.

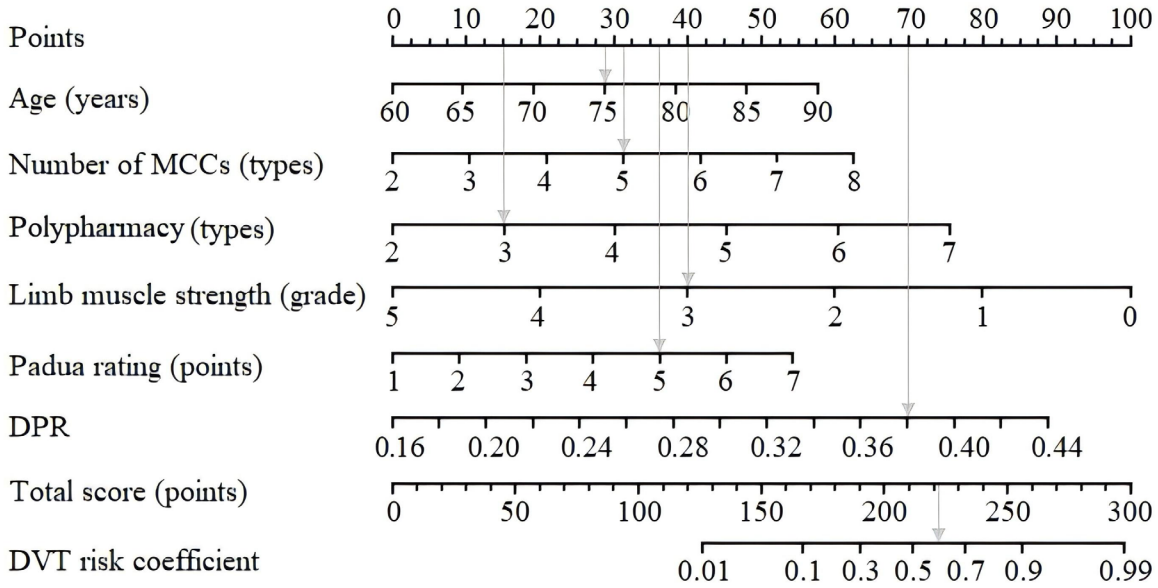

Figure 1. Nomogram prediction model of DVT risk in elderly patients with MCCs. Note: MCCs, Multiple chronic conditions; DPR, D-dimer/platelet ratio; DVT, Deep vein thrombosis.

Internal validation of the nomogram model

To evaluate the model's reliability, the entire development cohort (n=689) was randomly divided into a training group (482 cases) and an internal validation group (207 cases) at a 7:3 ratio. No significant differences were found in baseline characteristics between the two groups (including age, number of MCCs, polypharmacy, limb muscle strength at admission, Padua score and DPR) (all $P > 0.05$) (**Table 5**). To ensure comparability of data. Analysis shows that the AUC value were 0.846 for the training set and 0.831 and 0.831 for the validation set (**Figure 3**). Calibration curve analysis showed good agreement, with a calibration error of 0.011 for the training set and 0.026 for the validation set (**Figure 4**). DCA demonstrated that interventions based on the nomogram model provided a higher net benefit compared to the "treat-all" or "treat-none" strategies in both the training and validation sets (**Figure 5**).

External validation of the nomogram model

To assess the nomogram's predictive performance beyond the original development cohort, an independent cohort of 360 older adults with MCCs was used for external validation. There were no significant differences in baseline data between the modeling set and the external validation set ($P > 0.05$) (**Table 6**). *ROC* curve analysis showed that the nomogram achieved an AUC of 0.807 in the external validation cohort. Calibration curve analysis showed a calibration error of 0.059, and DCA showed that nomogram-based intervention strategies provided greater net benefit than either no intervention or intervention for all

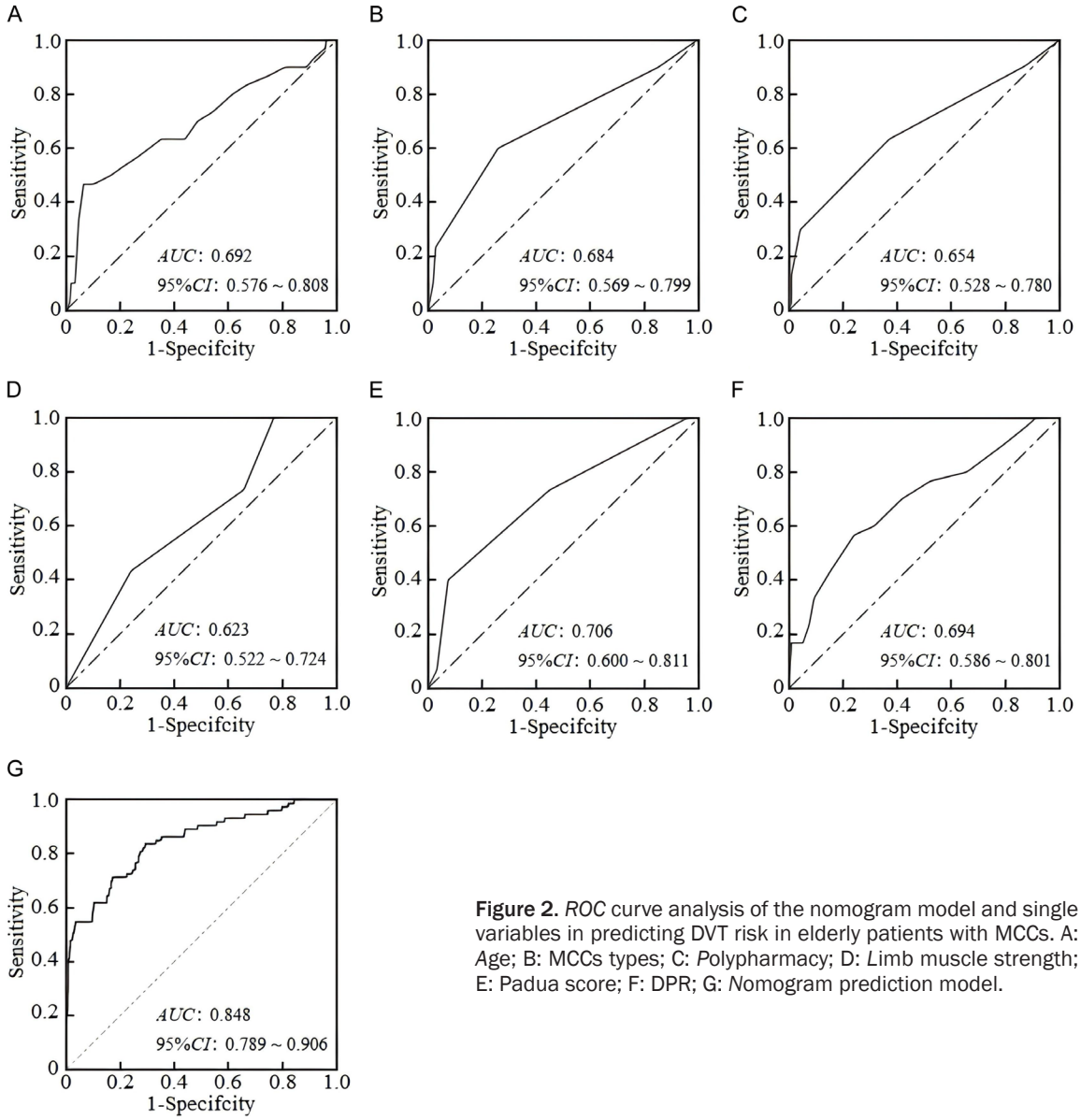

Figure 2. *ROC* curve analysis of the nomogram model and single variables in predicting DVT risk in elderly patients with MCCs. A: *A*ge; B: MCCs types; C: *P*olypharmacy; D: *L*imb muscle strength; E: Padua score; F: DPR; G: *N*omogram prediction model.

Table 4. Comparison of AUC values between nomogram model and single predictors

Item 1	Item 2	*AUC* value	Standard Error	95% *CI*	*Z* value	*P* value
Age	Nomogram model	-0.156	0.298	-0.268 - -0.043	-2.705	0.007
Number of MCCs	Nomogram model	-0.163	0.293	-0.290 - -0.037	-2.529	0.011
Polypharmacy	Nomogram model	-0.194	0.304	-0.329 - -0.058	-2.792	0.005
limb muscle strength	Nomogram model	-0.225	0.283	-0.348 - -0.101	-3.571	< 0.001
Padua rating	Nomogram model	-0.142	0.285	-0.264 - -0.020	-2.281	0.023
DPR	Nomogram model	-0.154	0.293	-0.286 - -0.022	-2.286	0.022

Note: MCCs, Multiple chronic conditions; DPR, D-dimer/platelet ratio.

patients (**Figure 6**). DeLong test showed no significant difference between the AUC values of the external validation set (0.807) and the modeling set (0.848) ($P > 0.05$). These findings confirm the good stability and generalizability of the nomogram model.

Table 5. Comparison of clinical data between the training group and the interval test group

Clinical data	Training group (*n*=482)	Test group (*n*=207)	$t/\chi^2/U$	*P*
Age (years)	72.68±5.42	72.71±4.39	0.070	0.944
BMI (kg/m^2)	22.79±3.58	22.50±3.07	1.016	0.310
Sex			0.405	0.525
Male	285 (59.13)	117 (56.52)		
Female	197 (40.87)	90 (43.48)		
Smoking history			1.115	0.291
Yes	130 (26.97)	64 (30.92)		
No	352 (73.03)	143 (69.08)		
Alcohol consumption history			2.586	0.108
Yes	114 (23.65)	61 (29.47)		
No	368 (76.35)	146 (70.53)		
Number of MCCs (types)	4.05±0.71	4.08±0.56	0.540	0.589
Polypharmacy (types)	3.35±0.43	3.40±0.46	1.370	0.171
limb muscle strength (level)	3.82±0.58	3.85±0.63	0.606	0.545
Padua rating (points)	3.43±0.72	3.41±0.57	0.355	0.723
Albumin (g/L^{-1})	38.16±5.37	38.09±5.18	0.159	0.874
Platelet ($\times10^9/L^{-1}$)	237.4 (158.2-338.4)	236.5 (157.9-336.1)	1.093	0.469
Fasting blood glucose ($mmol/L^{-1}$)	5.4 (4.2-9.8)	5.2 (4.1-9.7)	0.573	0.694
Triglyceride ($mmol/L^{-1}$)	1.3 (0.9-2.8)	1.3 (0.9-2.9)	0.376	0.737
Activated partial thromboplastin time (s)	28.34±3.58	28.21±3.45	0.442	0.659
Prothrombin time (s)	12.10±3.38	11.97±1.39	0.534	0.593
Fibrinogen (g/L^{-1})	3.31±0.95	3.23±0.84	1.048	0.295
D-dimer (mg/L^{-1})	0.65±0.27	0.62±0.19	1.451	0.147
DPR ($\times10^{-2}$)	0.26±0.08	0.27±0.07	1.560	0.119

Note: BMI, Body mass index; MCCs, Multiple chronic conditions; DPR, D-dimer/platelet ratio.

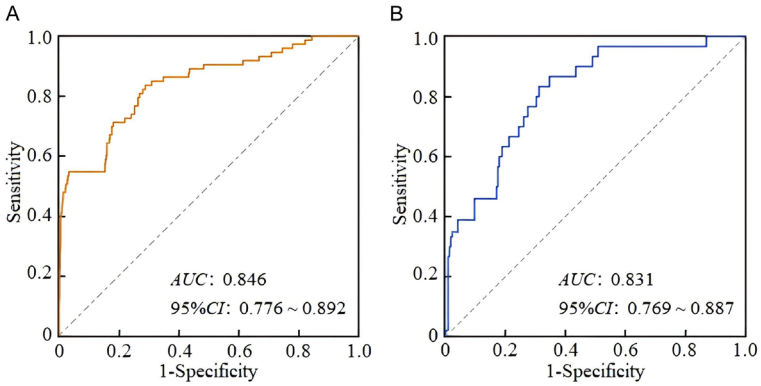

Figure 3. *ROC* curve analysis of the nomogram in training (A) and test (B) groups.

Discussion

DVT is a condition of venous return obstruction caused by abnormal blood coagulation within the deep veins [10, 11]. International epidemiological data show that adults aged ≥ 70 years have a three-fold higher DVT risk compared with younger and middle-aged adults (18-59 years) [12]. This underscores the elevated susceptibility to DVT among older hospitalized patients. This phenomenon stems from age-dependent physiological deterioration: diminished vascular elasticity, damaged venous intima, and venous-valve atrophy. These changes slow venous blood flow and induce blood stasis, rendering older adults as a high-risk group for DVT [13, 14]. Untreated thrombi may trigger severe consequences; dislodged thromboemboli can occlude blood vessels and precipitate acute thromboembolic events. Moreover, venous thrombosis can aggravate pre-existing chronic conditions (e.g., malignancy, renal fail-

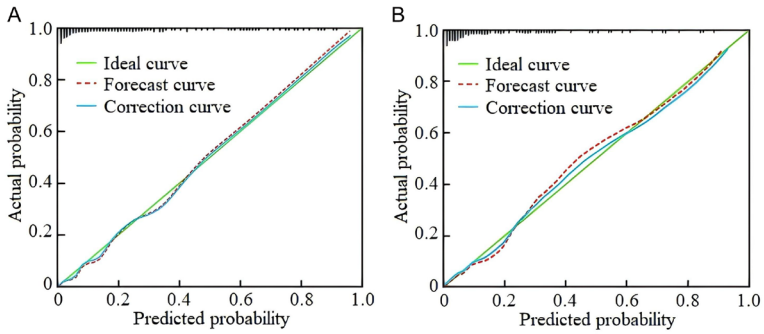

Figure 4. Calibration curve analysis of the nomogram in training (A) and test (B) groups.

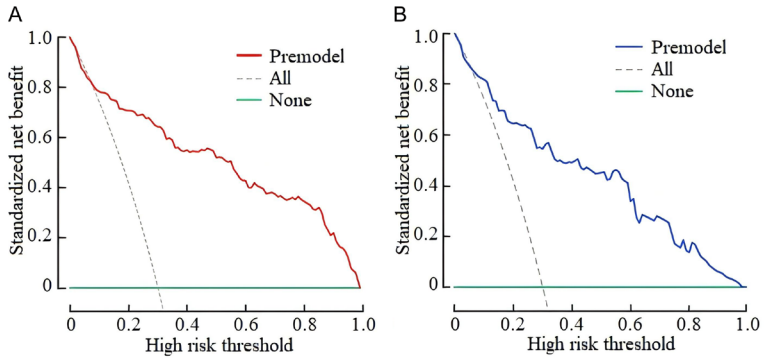

Figure 5. Decision curve analysis of the nomogram in training (A) and test (B) groups.

ure, cardiovascular-cerebrovascular diseases) and raise the risk of adverse clinical outcomes. Accordingly, identifying independent risk factors for DVT among older hospitalized adults with MCCs and developing a predictive risk-assessment nomogram is therefore critical. Such a model enables early-stage preventive interventions to lower DVT-related risk.

Advanced age is recognized as an independent risk factor for DVT development, with DVT risk rising progressively with age [15], which is consistent with the findings of the present study. This association may be attributed to deteriorated physical function and impaired vascular status elderly patients, which predisposes them to coagulation dysfunction and further elevates DVT susceptibility [16], thereby increasing the risk of DVT. In addition to age, multimorbidity is prevalent among elderly patients. Moreover, certain chronic diseases and their medications may also increase the risk probability of DVT. This study found that elderly MCC patients with a high number of MCCs and polypharmacy have a higher risk of developing DVT during hospitalization. The potential reason may be the interactive effects among multiple chronic diseases, which increase the patient's risk of DVT occurrence. We speculate this may be due to several interconnected mechanisms: ① Chronic diseases such as hypertension, diabetes mellitus, and hyperlipidemia can directly damage the vascular endothelium. For instance, blood pressure fluctuations in hypertensive patients generate abnormal shear stress, while hyperglycemia increases blood viscosity and promotes erythrocyte aggregation, both of which impair endothelial integrity [17]. Dyslipidemia impairs endothelium-dependent vasodilation and antioxidant capacity, further exacerbating endothelial dysfunction. Vascular endothelial injury promotes platelet adhesion and aggregation, activates the intrinsic coagulation pathway, and facilitates thrombus formation [18]. ② Inflammatory response: Chronic inflammatory conditions, including chronic obstructive pulmonary disease and rheumatoid arthritis, can activate platelets and the systemic coagulation cascade via inflammatory signaling pathways [19, 20], thereby promoting thrombosis. ③ Hypercoagulable state: Malignancies and autoimmune diseases can induce a hypercoagulable state [21, 22]. Abnormalities in blood components and coagulation function disrupt hemostatic balance, eventually contributing to thrombus generation. ④ Blood stasis: Chronic conditions such as cardiovascular disease and varicose veins may reduce blood flow velocity [23, 24], resulting in hemodynamic disturbances, including blood vortex formation and impaired perfusion. These hemodynamic abnormalities alter coagulation homeostasis and increase the risk of thrombosis. ⑤ Polypharmacy among MCCs patients: Complex drug interactions can disrupt drug metabolism and therapeutic effi-

Table 6. Comparison of baseline data between modeling set and external validation set

Baseline data	Modeling set (*n*=689)	External validation set (*n*=360)	t/χ^2	*P*
Age (years)	72.69±6.81	72.14±7.43	1.203	0.229
BMI (kg/m^2)	22.70±3.58	22.87±3.65	0.725	0.468
Sex			1.082	0.298
Male	402 (58.35)	222 (61.67)		
Female	287 (41.65)	138 (38.33)		
Smoking history			0.118	0.731
Yes	194 (28.16)	105 (29.17)		
No	495 (71.84)	255 (70.83)		
Alcohol consumption history			0.294	0.588
Yes	175 (25.40)	97 (26.94)		
No	514 (74.60)	263 (73.06)		
Number of MCCs (types)	4.06±0.69	4.01±0.72	1.098	0.273
Polypharmacy (types)	3.36±0.67	3.32±0.64	0.932	0.351
limb muscle strength (level)	3.83±0.54	3.79±0.52	1.154	0.249
Padua rating (points)	3.42±0.75	3.38±0.70	0.839	0.402

Note: BMI, Body mass index; MCCs, Multiple chronic conditions; DPR, D-dimer/platelet ratio.

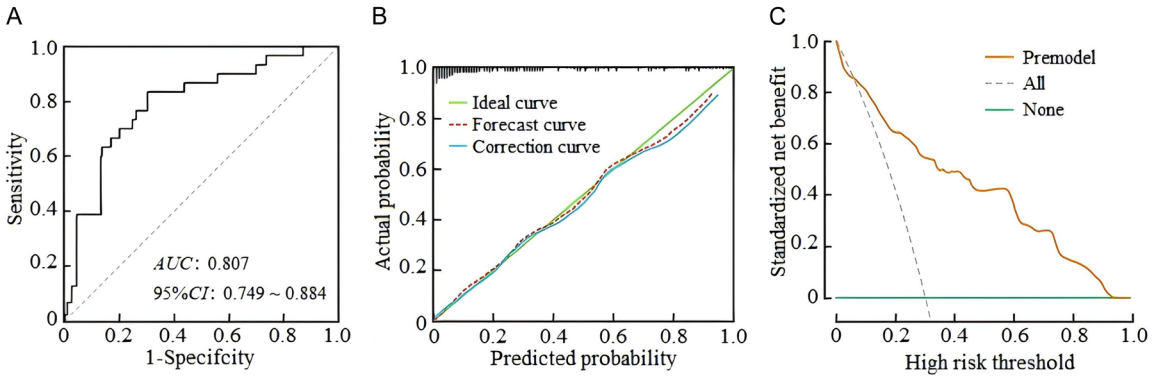

Figure 6. Validation of the nomogram model in the external validation cohort. A: *ROC* curve analysis; B: Calibration curve analysis; C: Decision curve analysis.

cacy. Certain medications exert procoagulant effects, whereas others interfere with endogenous anticoagulant mechanisms, collectively increasing thrombotic risk. Moreover, age-related decline in organ function reduces drug metabolic capacity in elderly patients, which may cause in vivo drug accumulation and further aggravate the risk of thrombus formation.

The Padua scale is a detailed tool for individualized venous thromboembolism risk stratification. Nevertheless, several studies have reported that the Padua scale exhibits limited predictive performance for in-hospital DVT and is often used in conjunction with D-dimer testing [25]. Elevated circulating D-dimer concentrations generally reflect simultaneous activation of the coagulation fibrinolytic cascades. While patients who developed DVT had significantly higher admission D-dimer levels in our univariate analysis, subsequent collinearity analysis identified significant multicollinearity between D-dimer, smoking history, platelet count and fasting blood glucose (*VIF* > 5). This statistical association can be explained by physiological pathways: smoking, hyperglycemia and elevated platelets, all which damage the vascular endothelium, trigger a systemic hypercoagulable state, and concurrently activate the coagulation and fibrinolytic systems [26-29]. Consequently, these four indicators exhibit highly consistent changing trends, accompa-

nied by substantial overlap in variable information, making D-dimer a less specific marker for predicting DVT in this population. Platelets, produced by megakaryocytes in hematopoietic tissue, function in adhesion, aggregation, release, and procoagulation. This study found that a higher D-dimer-to-platelet ratio was associated with a higher risk of DVT in elderly MCCs patients. This may be because fibrinolysis and partial coagulation pathway activation are mediated by platelets [30], suggesting a synergistic effect of platelet activation and fibrinolysis, which is better captured by their ratio. Therefore, the combined use of D-dimer and platelets can more comprehensively reflect the patient's coagulation dynamics, thereby providing a holistic perspective for clinical assessment of DVT risk and improving diagnostic efficacy. Physiological decline in elderly patients includes a natural, gradual decrease in muscle mass, strength and function [31, 32]. We hypothesize that the presence of multiple chronic diseases in elderly patients can lead to inflammatory states, metabolic disorders, nutritional deficiencies, and drug interactions, which may further impair muscle mass and strength, ultimately limiting daily activities. This study found that stronger limb muscle strength was a protective factor against DVT in elderly MCCs patients during hospitalization. This may be because elderly patients with stronger limb muscle strength can still actively perform effective limb flexion and extension during hospitalization, and they can walk in the hospital garden, exercise, and engage in other activities, with or without the assistance of family members or medical staff, thereby promoting systemic blood circulation [33]; consequently leading to a lower risk of DVT. Conversely, elderly patients with weaker limb muscle strength have limited physical activity capacity and may spend more time in bed resting, resulting in excessively slow blood flow velocity, slow clearance of procoagulant substances from the bloodstream, and an increased risk of DVT.

Early assessment of DVT is the first step in thrombus management in elderly patients and an important prerequisite for taking preventive measures against DVT. This study constructed a nomogram model based on the identified influencing factors for DVT risk in elderly MCCs patients (age, number of MCCs types, polypharmacy, Padua score, DPR, and limb muscle strength) to assess DVT risk in elderly MCCs patients. These indicators are common clinical parameters that are easily obtainable without additional examinations, making them worthy of promotion. After analysis and validation, the nomogram model constructed in this study achieved an *AUC* of 0.848. The modeling data were randomly divided into a training group and a test group according to the ratio of 7:3. The *AUC* values obtained by verification were 0.846 and 0.831, respectively. The calibration curve display errors were 0.011 and 0.026, respectively. The decision curve showed that the nomogram model could provide additional clinical net income. The *AUC* value verified externally was 0.807, the calibration curve showed an error of 0.059, and the decision curve showed that interventions based on the nomogram model could provide additional clinical net benefits; this indicates the stability and generalization ability of the nomogram model. The nomogram model enables individualized assessment of DVT risk in elderly patients, featuring intuitive and concise characteristics that can effectively guide medical staff in developing and optimizing patient thrombus management strategies. For example, for high-risk populations, antithrombotic drug intervention can be administered, with regular monitoring of coagulation indicators to adjust the antithrombotic drug dosage and avoid over- or under-treatment; physical prevention measures such as medical graduated compression stockings or intermittent pneumatic compression devices can also be applied; regular patient repositioning can help promote blood circulation; patients with strong limb muscle strength can be encouraged to perform limb exercises while bedridden to reduce the risk of blood stasis and thrombosis; in terms of diet, patients can be encouraged to follow a low-salt, low-fat, low-sugar, high-fiber dietary principle.

This study has several limitations. First, its retrospective, single-center design limits the generalizability of our findings. Although the established nomogram exhibited satisfactory predictive performance in out cohort, prospective multicenter studies are required to validate the stability of its prediction efficiency.

Conclusion

In-hospital DVT risk in elderly patients with MCCs is independently associated with advanced age, multiple types of MCCs, multiple drug treatments, high Padua scores, high DPR, and poor limb muscle strength. A nomogram prediction model constructed based on these factors can accurately assess the DVT risk in elderly MCCs patients.

Acknowledgements

This study was supported by the 2024 Academy level Research Start up Fund (YK202439).

Disclosure of conflict of interest

None.

Address correspondence to: Caifeng Guan, Geriatrics Department, Suzhou Ninth People's Hospital, No. 2666 Ludang Road, Taihu New Town, Wujiang District, Suzhou 215200, Jiangsu, China. Tel: +86-15862565059; E-mail: jy8371921@163.com

References

[1] Salive ME. Multimorbidity in older adults. Epidemiol Rev 2013; 35: 75-83.

[2] McMenamin A, Turi E, Schlak A and Poghosyan L. A systematic review of outcomes related to nurse practitioner-delivered primary care for multiple chronic conditions. Med Care Res Rev 2023; 80: 563-581.

[3] Zhu X, Wang Z, Yang X and Ning Z. About half of older adults have two or more chronic conditions at the same time: a systematic review and meta-analysis. Front Public Health 2025; 13: 1680745.

[4] Long C, Huang J, Liu D, Liu C, Wu M, Wu H, Deng J, Zhang Y, Shi L and Cui Y. Prevalence, combination patterns, and quality of life factors of multimorbidity among older adults in southern China based on the health ecological model. J Glob Health 2025; 15: 04215.

[5] Ju C, Liu H, Gong Y, Guo M, Ge Y, Liu Y, Luo R, Yang M, Li X, Liu Y, Li X, He T, Liu X, Huang C, Xu Y and Liu J. Changes in patterns of multimorbidity and associated with medical costs among Chinese middle-aged and older adults from 2013 to 2023: an analysis of repeated cross-sectional surveys in Xiangyang, China. Front Public Health 2024; 12: 1403196.

[6] Lv J, Li R, Yuan L, Yang XL, Wang Y, Ye ZW and Huang FM. Research on the frailty status and adverse outcomes of elderly patients with multimorbidity. BMC Geriatr 2022; 22: 560.

[7] Fang MC, Fan D, Sung SH, Witt DM, Schmelzer JR, Williams MS, Yale SH, Baumgartner C and Go AS. Treatment and outcomes of acute pulmonary embolism and deep venous thrombosis: the CVRN VTE study. Am J Med 2019; 132: 1450-1457, e1.

[8] Li Z, Wang M, Zhang L, Fan X, Tao X, Qi L, Ling M, Xiao X, Wu Y, Guo D and Qiao H. Neuronavigation-guided corticospinal tract mapping in brainstem tumor surgery: better preservation of motor function. World Neurosurg 2018; 116: e291-e297.

[9] Chen XL, Pan L and Wang Y. Validity of Padua risk assessment scale for assessing the risk of deep venous thrombosis in hospitalized patients. Zhonghua Nei Ke Za Zhi 2018; 57: 514-517.

[10] Ortel TL, Neumann I, Ageno W, Beyth R, Clark NP, Cuker A, Hutten BA, Jaff MR, Manja V, Schulman S, Thurston C, Vedantham S, Verhamme P, Witt DM, D Florez I, Izcovich A, Nieuwlaat R, Ross S, J Schünemann H, Wiercioch W, Zhang Y and Zhang Y. American Society of Hematology 2020 guidelines for management of venous thromboembolism: treatment of deep vein thrombosis and pulmonary embolism. Blood Adv 2020; 4: 4693-4738.

[11] Ben Salah R, Frikha F, Kaddour N, Saidi N, Snoussi M, Marzouk S, Jallouli M, Frigui M and Bahloul Z. Profil étiologiques des thromboses veineuses profondes en milieu de médecine interne: une étude rétrospective de 318 cas. Ann Cardiol Angeiol (Paris) 2014; 63: 11-16.

[12] Wolf S, Barco S, Di Nisio M, Mahan CE, Christodoulou KC, Ter Haar S, Konstantinides S, Kucher N, Klok FA, Cannegieter SC and Valerio L. Epidemiology of deep vein thrombosis. Vasa 2024; 53: 298-307.

[13] Li HL, Zhang H, Chan YC and Cheng SW. Prevalence and risk factors of hospital acquired venous thromboembolism. Phlebology 2025; 40: 266-274.

[14] Wang H, Rosendaal FR, Cushman M and van Hylckama Vlieg A. Procoagulant factor levels and risk of venous thrombosis in the elderly. J Thromb Haemost 2021; 19: 186-193.

[15] Karasu A, Šrámek A, Rosendaal FR, van der Geest RJ and van Hylckama Vlieg A. Aging of the venous valves as a new risk factor for venous thrombosis in the elderly: the BATAVIA study. J Thromb Haemost 2018; 16: 96-103.

[16] Mayrovitz HN, Aoki KC and Colon J. Chronic venous insufficiency with emphasis on the geriatric population. Cureus 2023; 15: e40687.

[17] Raya-Benítez J, Heredia-Ciuró A, Calvache-Mateo A, Martín-Núñez J, Valenza-Peña G, López-López L and Valenza MC. Effectiveness of non-instrumental early mobilization to reduce the incidence of deep vein thrombosis in hospital-

ized patients: a systematic review and meta-analysis. Int J Nurs Stud 2025; 161: 104917.
[18] Panchagnula N and Brasher WP. Hyperglycemia and venous thromboembolism. Diagnostics (Basel) 2024; 14: 1994.
[19] Tang X, Li Y, Ding Q, Sun Z, Zhang Y, Wang Y, Tian M and Liu J. Incidence and risk factors of deep vein thrombosis in patients with rheumatoid arthritis. Beijing Da Xue Xue Bao Yi Xue Ban 2024; 56: 279-283.
[20] Han W, Wang M, Xie Y, Ruan H, Zhao H and Li J. Prevalence of pulmonary embolism and deep venous thromboembolism in patients with acute exacerbation of chronic obstructive pulmonary disease: a systematic review and meta-analysis. Front Cardiovasc Med 2022; 9: 732855.
[21] Wang WD, Wei JP, Gao RQ, Yang QC, Chen T, Zhou HK, Dong DH, Yang XS, Yu PF, Zhang Y, Li XH and Ji G. A retrospective study of the role of preoperative ultrasonography in the detection of deep vein thrombosis in 1750 patients with gastric and colorectal cancers. Thromb Res 2022; 216: 52-58.
[22] Zhou Y, Jiang H, Wei H, Xiao X, Liu L, Ji X and Zhou C. Cerebral venous thrombosis in patients with autoimmune disease, hematonosis or coronavirus disease 2019: many familiar faces and some strangers. CNS Neurosci Ther 2023; 29: 2760-2774.
[23] Hajra A, Goel A, Malik AH, Isath A, Shrivastav R, Gupta R, Das S, Krittanawong C and Bandyopadhyay D. Impact of COVID-19 on patients hospitalized with deep vein thrombosis and/or pulmonary embolism: a nationwide analysis. Curr Probl Cardiol 2023; 48: 101553.
[24] Stark K and Massberg S. Interplay between inflammation and thrombosis in cardiovascular pathology. Nat Rev Cardiol 2021; 18: 666-682.
[25] Zhou C, Guang Y, Luo Y, Ge H, Wei H, Liu H, Zhang J, Pan P, Zhang J, Peng L, Aili A, Liu Y, Pu J, Zhong X, Wang Y, Yi Q and Zhou H; MAGNET AECOPD Registry Investigators. Superior predictive value of d-dimer to the padua prediction score for venous thromboembolism in inpatients with AECOPD: a multicenter cohort study. Int J Chron Obstruct Pulmon Dis 2022; 17: 2711-2722.
[26] Yu Y, Zhu C, Lin Y, Qian Q, Shen X, Zou W, Wang M, Gong J, Chen M, Liu L, Yu R, Shen Q, Shao L and Zhu B. Plasma D-dimer levels are associated with disease progression in diabetic nephropathy: a two-center cohort study. Ren Fail 2023; 45: 2285868.
[27] Zhang M, Zhang J, Zhang Q, Yang X, Shan H, Ming Z, Chen H, Liu Y, Yin J and Li Y. D-dimer as a potential biomarker for the progression of COPD. Clin Chim Acta 2016; 455: 55-59.
[28] Zhao F, Zhao J, Shan Y, Zheng Y, Shi Y, Song C, Cheng Y, Li Y, Guo S, Chang C and He D. Cross-sectional study of clinical features of rheumatoid arthritis in elderly and young onset. Am J Med Sci 2026; 371: 473-481.
[29] Yu J, Li D, Lei D, Yuan F, Pei F, Zhang H, Yu A, Wang K, Chen H, Chen L, Wu X, Tong X and Wang Y. Tumor-specific d-dimer concentration ranges and influencing factors: a cross-sectional study. PLoS One 2016; 11: e0165390.
[30] Heestermans M, Poenou G, Duchez AC, Hamzeh-Cognasse H, Bertoletti L and Cognasse F. Immunothrombosis and the role of platelets in venous thromboembolic diseases. Int J Mol Sci 2022; 23: 13176.
[31] Di Nisio M, Di Iorio A, Porreca E, Abate M, Ferrante N, Bandinelli S, Guralnik J, Molino-Lova R, Cuccurullo F and Ferrucci L. Obesity, poor muscle strength, and venous thromboembolism in older persons: the InCHIANTI study. J Gerontol A Biol Sci Med Sci 2011; 66: 320-325.
[32] Keller K and Engelhardt M. Strength and muscle mass loss with aging process. Age and strength loss. Muscles Ligaments Tendons J 2014; 3: 346-350.
[33] Tegtbur U, Haufe S and Busse MW. Application and effects of blood flow restriction training. Unfallchirurg 2020; 123: 170-175.