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Association of motoric cognitive risk syndrome with falls in older adults: findings from three longitudinal studies

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Abstract

Background Falls pose a significant threat to older adults' health, affecting one-third of individuals aged over 65 annually and resulting in severe injuries despite numerous screening tools. While motoric cognitive risk syndrome (MCR) is established as a dementia risk factor, its utility as a fall prediction tool remains unclear due to inconsistent findings across populations. This study therefore aims to elucidate the associations between motoric cognitive risk syndrome and falls among older adults.

Methods Participants aged ≥ 60 years were selected from the English Longitudinal Study of Aging (ELSA), the Health and Retirement Study (HRS), and the China Health and Retirement Longitudinal Study (CHARLS). Subjective cognitive complaints (SCC) were assessed based on participants' responses to standardized questionnaire items. Slow gait was defined as a gait speed of more than one standard deviation below the age- and gender-specific mean values. MCR was diagnosed when both SCC and slow gait were present. Outcomes for investigation included falls, multiple falls, and fall-related injuries. Logistic regression analysis was conducted to examine the longitudinal association between MCR, its components, and the occurrence of falls over the following four years.

Results Ultimately, 10,373 participants were included in the analysis. After adjusting for covariates, MCR was associated with an increased risk of falls over the next four years, with relative increases of 60.0%, 50.5%, and 34.1% observed in the ELSA, HRS, and CHARLS cohorts, respectively. MCR was also linked to an elevated risk of multiple falls, although no significant association was found with fall-related injuries.In the fully adjusted models, slow gait alone did not show an independent association across all cohorts. Only MCR emerged as a significant and stable predictor of future falls, while further research is needed to clarify the role of SCC.

Conclusions This large-scale prospective study found that MCR significantly predicts falls in older adults, highlighting its potential as a clinically useful screening tool integrating cognitive and motor parameters for improved fall risk identification.

Keywords Motoric cognitive risk syndrome1, Cognitive dysfunction2, Fall risk$_3$, Subjective cognitive complaint$_4$, Gait speed$_5$

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Introduction

Falls, serving as the second leading cause of injury-related death in older adults, pose a significant threat to health and well-being [1, 2]. Approximately one-third of individuals aged 65 and older experience at least one fall annually, with the incidence increasing to around 50% in those over 80 years of age [3, 4], with a substantial proportion resulting in severe injuries such as hip fractures and traumatic brain injuries [5]. Despite up to 26 screening tools for assessing fall risk, the prevalence of falls remains unchanged, which causes a significant burden on the healthcare and economic systems [6, 7]. This is likely due to the multifactorial nature of falls, which can result from a combination of physical, cognitive, and environmental factors that are not always fully captured by current screening tools [8]. Therefore, developing simple and practical assessment tools to evaluate cumulative fall risk is crucial.

Many existing tools focus primarily on physical factors, such as gait or balance, while neglecting the cognitive aspects, which can also contribute significantly to fall risk [9, 10]. The role of motoric cognitive risk syndrome (MCR), characterized by both subjective cognitive complaint (SCC) and slow gait as an independent risk factor for dementia has been confirmed across various populations [11]. However, its potential as a fall screening tool requires further investigation in diverse settings. Our research aims to address these gaps by incorporating both cognitive and motoric components into the fall risk assessment. While some studies have explored the relationship between MCR and falls in individuals aged 60 years and older, their findings have often lacked consistency, with follow-up durations limited to a single time point [12, 13]. For example, Beauchet et al. (2019) [14] demonstrated that MCR could predict future fall risk in French women, while Lord et al. (2020) [15] found no such association in one of the two ethnic groups in New Zealand. These discrepancies may be attributed to various factors, including race, age, gender, and other demographic characteristics of the study populations.

Given that MCR can be assessed using relatively simple methods, our goal is to evaluate its applicability in diverse settings, focusing on three countries in the Northern Hemisphere: the United Kingdom, the United States, and China. We hypothesize that MCR is linked to increased fall risk in older adults, with its components (SCC and slow gait) serving as key predictors across populations. Three prospective longitudinal studies with larger sample sizes and extended follow-up duration are essential to test the relationship between MCR, its components (SCC and slow gait) and falls. To fill the knowledge gaps, we, therefore, conducted three prospective studies using the data from the English Longitudinal Study of Aging (ELSA), the Health and Retirement Study (HRS), and the China Health and Retirement Longitudinal Study (CHARLS) to explore the association of MCR and falls risk among older adults from global perspectives.

Materials and methods

Study participants

Our analysis included three nationally representative longitudinal cohorts from some of the largest countries in the Northern Hemisphere: ELSA, HRS, and CHARLS. Figure 1 illustrates the study population selection process. Among the 44,294 participants who were aged ≥ 60 years, completed baseline surveys from ELSA (waves 4–6), HRS (waves 10–12), and CHARLS (waves 1–3), we initially excluded 31,112 participants due to missing data on MCR calculation at baseline. An additional 604 participants were excluded for missing basic information, and 1,646 participants were removed for missing data on potential confounding factors. Furthermore, 559 participants were excluded due to missing follow-up data on falls. Ultimately, 10,373 eligible participants were included in the final analysis.

Assessment of MCR

MCR diagnosis was defined as the concurrent presence of slow gait speed and SCC in participants without dementia or significant mobility impairment (the inability to ambulate independently or with assistive devices) [16]. Slow gait was operationalized as a walking speed (cm/s) more than one standard deviation below the age- and sex-specific population mean [17]. SCC was assessed based on participants' responses to standardized questionnaire items, which asked them to rate their current memory or compare it to their memory at the time of the previous interview [18].

Definition of falls and follow-up

In the ELSA, HRS, and CHARLS, falls were ascertained based on questionnaires of self-reported incidents at subsequent follow-ups [19–21]. The assessments of falls involved asking participants to answer the questions "fallen in the last two years", "number of falls" (except for CHARLES) and "fall-related injuries". Individuals reporting two or more falls were classified as having "multiple falls," and the outcomes were categorized into three groups: "history of falls," "multiple falls," and "falls injuries."

Measurements of covariates

In this study, demographic characteristics, physical measurements, behavioral habits, and chronic diseases were included as the covariates, all collected at baseline (including ELSA wave 4, HRS wave 10, and CHARLS

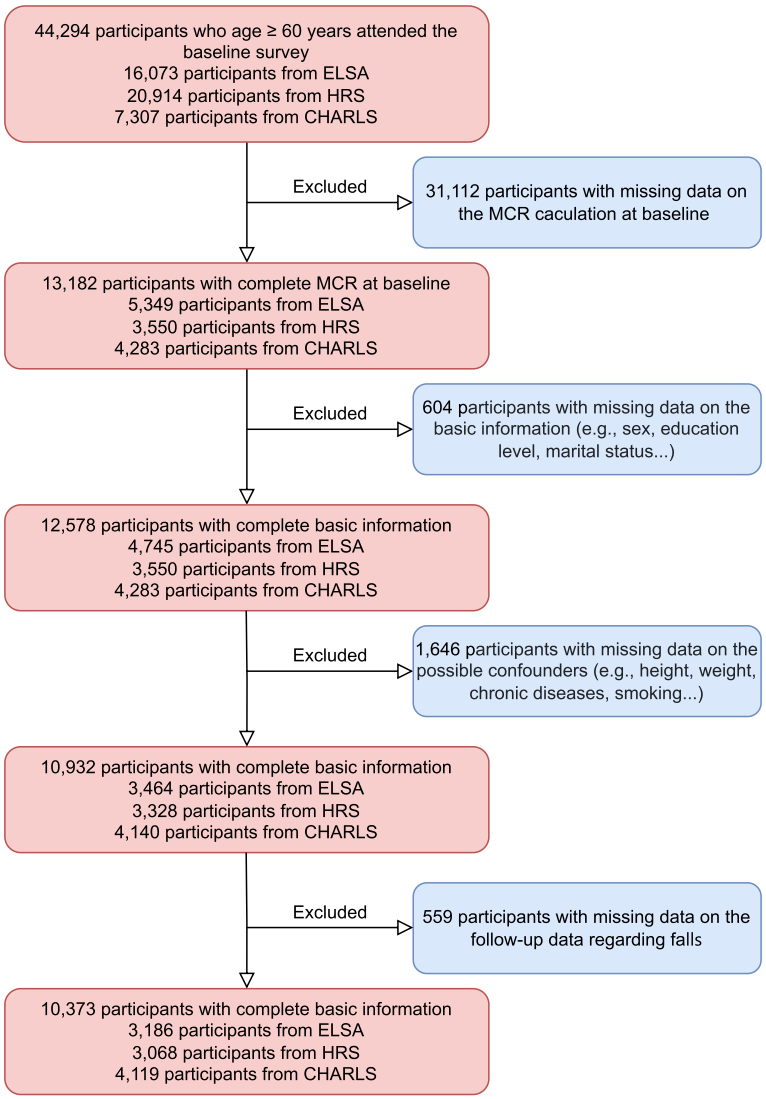

Fig. 1 Flowchart of participants' selection

wave 1)—demographic characteristics comprised age (in years), sex, level of education, marital status. Physical measurements include systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, waist circumstances, and body mass index (BMI). Behavioural habits consisted of smoking and drinking history. Chronic diseases were self-reported physician-diagnosed, including hypertension, diabetes, dyslipidemia (lacked in ELSA), cancer, chronic lung disease, liver disease (lacked in ELSA), kidney disease (lacked in ELSA), arthritis, heart disease, stroke, psycho problem, stomach digestive disease (lacked in ELSA) and asthma. The level of education was re-defined into two groups in three cohort studies: less than lower secondary education and secondary or above. We divided the BMI category into four groups within the cutoff value of 18.5, 24.9, and 29.9, named "underweight," "normal," "overweight," and "obesity." We also count the number of chronic disease conditions into four categories in the inclusion of covariates.

Statistical analysis

The baseline characteristics of the participants were summarized by MCR using descriptive statistics. Continuous variables are reported as the mean ± SD for normally distributed data and the median with interquartile range for skewed distributions. Cohort differences were evaluated using ANOVA for normally distributed data and the Kruskal–Wallis test for skewed distributions [22]. Categorical variables are expressed as frequencies with

percentages, and cohort comparisons were performed using the $\chi 2$ test [23].

Logistic regression models were constructed, and odds ratio (OR) and 95% confidence intervals (CIs) were estimated to assess the associations between MCR and the risk of incident falls, multiple falls, and fall-related injuries. The reported OR represented the odds of experiencing a fall among individuals with MCR compared to references (including those without MCR and healthy persons). In addition to Model 1, which had no adjustment, two models adjusted for confounding variables. Model 2 included demographic characteristics and Model 3 adjusted for all covariates from Model 2, along with smoking status, drinking status, SBP, DBP, height, weight, BMI, and several chronic disease conditions. Additionally, participants without slow gait and SCC were defined as the healthy reference group, and we also estimated the OR for comparisons between this group and individuals with MCR.

To assess the robustness of the study, sensitivity analyses were conducted using logistic regression after excluding participants with a history of falls. Additionally, cox proportional hazards regression models were applied to evaluate the longitudinal association between MCR and incident falls, excluding individuals with a fall history at baseline. Hazard ratios (HRs) and corresponding 95% confidence intervals (CIs) were calculated. Subgroup analyses were also performed, stratifying outcomes by age (< 75 vs ≥ 75 years), sex, education level, marital status, fall history, and smoking and drinking status. These subgroup analyses used comprehensive regression models fully adjusted for confounding factors. A meta-analysis was conducted to assess the overall effect of MCR on falls by pooling the results from the three studies. All statistical analyses were performed using R software version 4.0.2, and a two-sided *P* value of less than 0.05 was considered statistically significant.

Result

Baseline characteristics of the study population

After applying the inclusion and exclusion criteria, a total of 10,373 participants were included in the present study, comprising 3,186 individuals from ELSA (52.2% female; mean age: 69.6 years), 3,068 from HRS (57.3% female; mean age: 75.2 years), and 4,199 from CHARLS (48.8% female; mean age: 67.1 years), as summarized in Table 1. Across the ELSA, HRS, and CHARLS cohorts, participants with MCR were more likely to be single, had lower educational attainment, a higher burden of chronic conditions, and were more likely to engage in alcohol consumption. Participants with MCR were older and had higher BMI in both the ELSA and CHARLS cohorts. Notably, individuals with MCR in the ELSA cohort exhibited lower DBP, whereas participants with MCR in the CHARLS cohort showed higher DBP.

Association between MCR and incident falls

In total, 1369 (43.0%), 1512 (49.3%), and 1247 (30.3%) participants have fallen during the 4-year follow-up in the ELSA, HRS, and CHARLS cohorts, respectively (Table 1). Figure 2 showed that over the last 4 years, fall accident rates were 8%, 7.2%, and 15.5% among participants with MCR in ELSA, HRS and CHARLS, respectively. Notably, participants with MCR exhibited higher fall accident rates than those without MCR (chi-squared test: $P < 0.01$).

Univariate logistic model analyses (Model 1) revealed a highly significant association between MCR and incident falls compared to those without MCR (ELSA: OR, 1.785 [95% CI, 1.332–2.399]); (HRS: OR, 1.649 [95% CI, 1.214–2.254]); (CHARLS: OR, 1.649 [95% CI, 1.207–1.775]) (Table 2; Model 1). After controlling for covariates in Models 2 and 3, the association of MCR with falls slightly attenuated but remained significant (ELSA: OR, 1.600 [95% CI, 1.179–2.178]); (HRS: OR, 1.505 [95% CI, 1.095–2.082]); (CHARLS: OR, 1.341 [95% CI, 1.099–1.632]) (Table 2; Model 3). Additionally, we calculated the odds ratios for multiple falls and fall-related injuries. Notably, after full adjustment for covariates, MCR was associated with a 139.6% and 42.4% increased likelihood of falls in ELSA and HRS, respectively. However, no significant association was found between MCR and fall-related injuries in any cohorts.

Association between MCR components and incident falls

After controlling for confounders, slow gait was not associated with future falls in any cohorts. In contrast, SCC was strongly associated with future falls in the fully adjusted models in two of the three cohorts: HRS (OR, 1.259 [95% CI, 1.074–1.477]); CHARLS (OR, 1.491 [95% CI, 1.193–1.875]) (Table 3; Model3). An increasing trend was observed in ELSA but did not reach statistical significance. Moreover, when these two indicators were combined to define MCR, the results remained consistent across all three cohorts, showing a 73.9%, 72.7%, and 92.4% increased risk compared to the healthy group (Table 3; Model 3).

Sensitivity analyses

We conducted some sensitivity analyses to assess the robustness of the association between MCR and future falls. By deleting the people who have fallen in the past 2 years before baseline, we aimed to determine whether the association between MCR and future falls remained significant, even in the absence of fall history, which may be subject to recall bias. The multivariate logistic

Table 1 Baseline characteristics participants for MCR analyses

Variables		ELSA				HRS				CHARLS			
		Overall	Non-MCR	MCR	*P* value	Overall	Non-MCR	MCR	*P* value	Overall	Non-MCR	MCR	*P* value
Number		3186	2993	193		3068	2889	179		4119	3607	512	
Age,mean(SD),years		69.6(7.3)	69.5(7.3)	70.6(8.3)	0.045	75.2(6.6)	75.2(6.6)	75.5(7.1)	0.555	67.1(5.8)	66.9(5.8)	68.2(6.1)	< 0.001
Sex,n(%)	Female	1662(52.2)	1575(52.6)	87(45.1)	0.05	1759(57.3)	1661(57.5)	98(54.7)	0.52	2012(48.8)	1744(48.4)	268(52.3)	0.1
	Male	1524(47.8)	1418(47.4)	106(54.9)		1309(42.7)	1228(42.5)	81(45.3)		2107(51.2)	1863(51.6)	244(47.7)	
Education level,n(%)	Less than lower secondary education	1311(41.1)	1194(39.9)	117(60.6)	< 0.001	520(16.9)	457(15.8)	63(35.2)	< 0.001	3903(94.8)	3406(94.4)	497(97.1)	0.016
	Secondary or above	1875(58.9)	1799(60.1)	76(39.4)		2548(83.1)	2432(84.2)	116(64.8)		216(5.2)	201(5.6)	15(2.9)	
Marital,n(%)	Married	2226(69.9)	2115(70.7)	111(57.5)	< 0.001	1879(61.2)	1783(61.7)	96(53.6)	0.038	3330(80.8)	2950(81.8)	380(74.2)	< 0.001
	Single	960(30.1)	878(29.3)	82(42.5)		1189(38.8)	1106(38.3)	83(46.4)		789(19.2)	657(18.2)	132(25.8)	
Smoking,n(%)	NO	1227(38.5)	1166(39.0)	61(31.6)	0.05	1381(45.0)	1308(45.3)	73(40.8)	0.273	2354(57.1)	2048(56.8)	306(59.8)	0.219
	YES	1959(61.5)	1827(61.0)	132(68.4)		1687(55.0)	1581(54.7)	106(59.2)		1765(42.9)	1559(43.2)	206(40.2)	
Drinking,n(%)	NO	327(10.3)	278(9.3)	49(25.4)	< 0.001	1488(48.5)	1372(47.5)	116(64.8)	< 0.001	2426(58.9)	2097(58.1)	329(64.3)	0.01
	YES	2859(89.7)	2715(90.7)	144(74.6)		1580(51.5)	1517(52.5)	63(35.2)		1693(41.1)	1510(41.9)	183(35.7)	
SBP,mean(SD),mmHg		134.6(17.7)	134.7(17.7)	133.0(17.8)	0.206	134.3(20.6)	134.2(20.6)	134.6(20.8)	0.802	135.0(22.4)	134.5(22.3)	138.3(23.5)	< 0.001
DBP,mean(SD),mmHg		73.6(10.8)	73.7(10.8)	71.3(10.7)	0.002	78.1(11.4)	78.2(11.4)	76.9(10.3)	0.151	74.9(11.7)	74.7(11.6)	76.3(12.0)	0.004
Height,mean(SD),m		1.7(0.1)	1.7(0.1)	1.6(0.1)	0.061	1.7(0.1)	1.7(0.1)	1.7(0.1)	0.36	1.6(0.1)	1.6(0.1)	1.6(0.1)	0.004
Weight,mean(SD),kg		77.1(15.1)	76.9(15.0)	81.2(16.9)	< 0.001	78.3(17.6)	78.2(17.5)	80.4(19.4)	0.106	56.3(11.2)	56.3(11.0)	55.8(12.5)	0.27
Waist,mean(SD),cm		97.4(12.9)	97.1(12.8)	101.9(13.8)	< 0.001	101.2(14.6)	101.0(14.5)	104.5(15.9)	0.002	84.2(12.4)	84.2(12.2)	83.9(13.4)	0.613
BMI,n(%)	Normal	772(24.2)	741(24.8)	31(16.1)	0.001	912(29.7)	858(29.7)	54(30.2)	0.756	2638(64.0)	2321(64.3)	317(61.9)	0.004
	Obesity	958(30.1)	877(29.3)	81(42.0)		901(29.4)	843(29.2)	58(32.4)		164(4.0)	132(3.7)	32(6.2)	
	Overweight	1441(45.2)	1360(45.4)	81(42.0)		1214(39.6)	1149(39.8)	65(36.3)		906(22.0)	807(22.4)	99(19.3)	
	Underweight	15(0.5)	15(0.5)	0(0.0)		41(1.3)	39(1.3)	2(1.1)		411(10.0)	347(9.6)	64(12.5)	
Number of chronic conditions(%)	≥ 3	1000(31.4)	895(29.9)	105(54.4)	< 0.001	1298(42.3)	1192(41.3)	106(59.2)	< 0.001	906(22.0)	765(21.2)	141(27.5)	< 0.001
	0	512(16.1)	501(16.7)	11(5.7)		250(8.1)	242(8.4)	8(4.5)		1085(26.3)	984(27.3)	101(19.7)	
	1	884(27.7)	849(28.4)	35(18.1)		626(20.4)	603(20.9)	23(12.8)		1212(29.4)	1059(29.4)	153(29.9)	
	2	790(24.8)	748(25.0)	42(21.8)		894(29.1)	852(29.5)	42(23.5)		916(22.2)	799(22.2)	117(22.9)	
Slow gait,n(%)	Normal gait	2823(88.6)	2823(94.3)	0(0.0)	< 0.001	2684(87.5)	2684(92.9)	0(0.0)	< 0.001	3522(85.5)	3522(97.6)	0(0.0)	< 0.001
	Slow gait	363(11.4)	170(5.7)	193(100.0)		384(12.5)	205(7.1)	179(100.0)		597(14.5)	85(2.4)	512(100.0)	
Subjective cognitive complaints,n(%)	NO	1879(59.0)	1879(62.8)	0(0.0)	< 0.001	1775(57.9)	1775(61.4)	0(0.0)	< 0.001	613(14.9)	613(17.0)	0(0.0)	< 0.001
	YES	1307(41.0)	1114(37.2)	193(100.0)		1293(42.1)	1114(38.6)	179(100.0)		3506(85.1)	2994(83.0)	512(100.0)	
MCR,n(%)	NO	2993(93.9)	2993(100.0)	0(0.0)	< 0.001	2889(94.2)	2889(100.0)	0(0.0)	< 0.001	3607(87.6)	3607(100.0)	0(0.0)	< 0.001
	YES	193(6.1)	0(0.0)	193(100.0)		179(5.8)	0(0.0)	179(100.0)		512(12.4)	0(0.0)	512(100.0)	

Table 1 (continued)

Variables		ELSA				HRS				CHARLS			
		Overall	Non-MCR	MCR	*P* value	Overall	Non-MCR	MCR	*P* value	Overall	Non-MCR	MCR	*P* value
Fall history,n(%)	NO	2412(75.7)	2300(76.8)	112(58.0)	< 0.001	1984(64.7)	1886(65.3)	98(54.7)	0.005	789(19.2)	676(18.7)	113(22.1)	0.083
	YES	774(24.3)	693(23.2)	81(42.0)		1084(35.3)	1003(34.7)	81(45.3)		3330(80.8)	2931(81.3)	399(77.9)	
Fall,n(%)	NO	1817(57.0)	1733(57.9)	84(43.5)	< 0.001	1556(50.7)	1486(51.4)	70(39.1)	0.002	2872(69.7)	2553(70.8)	319(62.3)	< 0.001
	YES	1369(43.0)	1260(42.1)	109(56.5)		1512(49.3)	1403(48.6)	109(60.9)		1247(30.3)	1054(29.2)	193(37.7)	
Multiple falls,n(%)	NO	2625(82.5)	2504(83.7)	121(63.4)	< 0.001	2131(69.6)	2026(70.3)	105(59.0)	0.002	/	/	/	/
	YES	558(17.5)	488(16.3)	70(36.6)		930(30.4)	857(29.7)	73(41.0)		/	/	/	
Fall injuries,n(%)	NO	951(69.5)	883(70.1)	68(62.4)	0.115	2283(74.6)	2152(74.6)	131(73.6)	0.823	1095(87.9)	928(88.2)	167(86.1)	0.474
	YES	417(30.5)	376(29.9)	41(37.6)		778(25.4)	731(25.4)	47(26.4)		151(12.1)	124(11.8)	27(13.9)	
Follow time,mean(SD),years		3.4(0.9)	3.4(0.9)	3.1(1.0)	< 0.001	3.3(1.0)	3.3(1.0)	2.9(1.0)	< 0.001	3.6(0.8)	3.6(0.8)	3.5(0.9)	0.002

Abbreviations: *SD* Standard deviation, *BMI* Body Mass Index, *MCR* Motoric Cognitive Risk syndrome, *Non-MCR* participants without SCC or slow gait, *SCC* Subjective Cognitive Complaint, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure

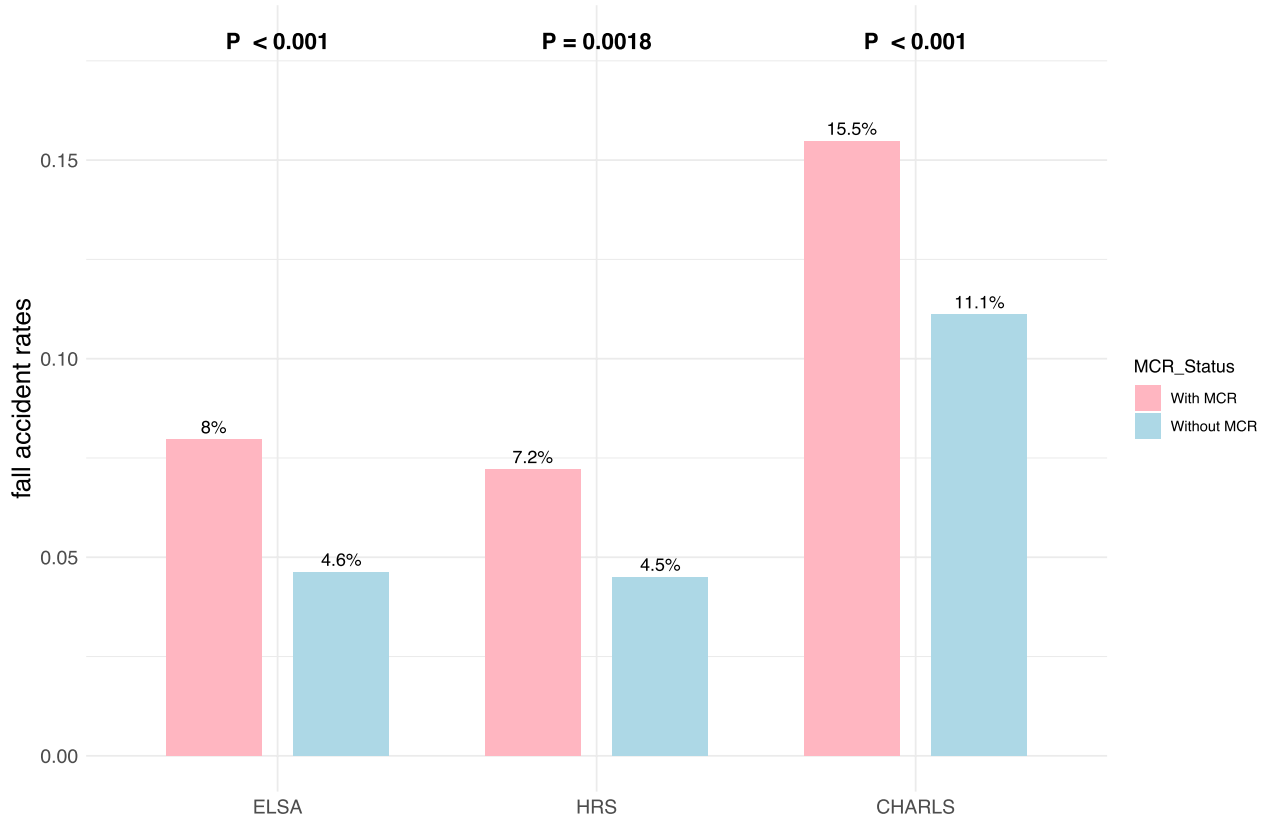

Fig. 2 Comparison of fall accident rates in elderly participants with and without MCR across cohorts

regression model indicated that, after full adjustment for covariates, MCR was associated with a 105.6% increased risk of future falls in ELSA, 58.3% in HRS, and 29.4% in CHARLS, compared to non-MCR participants (Table 4; Model 3). Moreover, we also assessed the longitudinal association between MCR and incident falls to strengthen the conclusion. Multivariate Cox proportional hazard analysis further indicated that MCR remained an independent significant predictor for falls incidence in Model 3 (ELSA: HR, 1.414 [95% CI, 1.018–1.966]); (HRS: HR, 1.442 [95% CI, 1.159–1.794]); (CHARLS: HR, 1.251 [95% CI, 1.035–1.513]) (Table 5).

Further evaluation of the odds ratio for MCR and fall incidence was performed across various study population subgroups, including sex, age, education status, marital status, fall history, and smoking and drinking status (Supplementary Figs. 1–3). All outcomes were derived from multivariable regression models. The association between MCR and falls was more pronounced among male participants (p for interaction < 0.01 in ELSA) than female. Aside from sex, the overall trend remained consistent across all three cohorts. The meta-analysis of the three studies on the overall analyses and subgroup analyses were consistent with those of the original single study (Fig. 3).

Discussion

In this study involving three prospective cohorts, we examined the associations between MCR and its components (SCC and slow gait) with future falls. The primary finding of our study was that MCR independently predicted falls over a 4-year follow-up period, even after adjusting for all covariates. In contrast, no consistent association was found between slow gait, SCC, and an increased risk of future falls. Participants with MCR exhibited elevated risks of incident falls and multiple falls, but no significant association was observed with fall-related injuries. To our knowledge, this is the first study to highlight the predictive value of MCR for future falls across three cohorts, providing a comparison to other components.

In this prospective study, we observed that the MCR demonstrated greater sensitivity than non-MCR measures in predicting the risk of future falls, thereby corroborating findings from previous studies [13, 14, 24]. Furthermore, our pooled analysis revealed a 43.1% increase in the risk of falls associated with the MCR

Table 2 Logistic regression analysis of future falls/multiple falls/injuries by fall (dependent variables) and MCR(independent variable)

		ELSA			HRS			CHARLS		
	Variables	**Model1 OR[95%CI]**	**Model2 OR[95%CI]**	**Model3 OR[95%CI]**	**Model1 OR[95%CI]**	**Model2 OR[95%CI]**	**Model3 OR[95%CI]**	**Model1 OR[95%CI]**	**Model2 OR[95%CI]**	**Model3 OR[95%CI]**
	Non-MCR	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Fall	MCR	1.785 (1.332–2.399)***	1.762 (1.308–2.383)***	1.600 (1.179–2.178)**	1.649 (1.214–2.254)**	1.643 (1.201–2.262)**	1.505 (1.095–2.082)*	1.465 (1.207–1.775)***	1.407 (1.157–1.708)***	1.341 (1.099–1.632)**
Multiple Falls	MCR	2.968 (2.169–4.035)***	2.871 (2.086–3.926)***	2.396(1.725–3.308)***	1.644 (1.203–2.235)**	1.607 (1.170–2.196)**	1.424 (1.030–1.958)*	/	/	/
Fall Injuries	MCR	1.416 (0.937–2.115)	1.572 (1.026–2.384)*	1.513 (0.977–2.322)	1.056 (0.742–1.478)	1.017 (0.711–1.432)	1.015 (0.708–1.434)	1.210 (0.760–1.867)	1.162 (0.728–1.797)	1.142 (0.710–1.783)

Model 1:Univariate logistic regression analysis

Model 2:Adjusted for age, sex, level of education, marital status

Model 3:Adjusted for all covariates from Model 2, along with smoking status, drinking status, systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, body mass index (BMI), and chronic disease conditions

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 3 Logistic regression analysis of future falls (dependent variable) and MCR, SCC, slow gait (independent variables)

Variables	ELSA			HRS			CHARLS		
	Model1 OR[95%CI]	Model2 OR[95%CI]	Model3 OR[95%CI]	Model1 OR[95%CI]	Model2 OR[95%CI]	Model3 OR[95%CI]	Model1 OR[95%CI]	Model2 OR[95%CI]	Model3 OR[95%CI]
Health	1	1	1	1	1	1	1	1	1
Slow gait	1.374 (1.002–1.885)*	1.382 (0.999–1.911)	1.248 (0.892–1.744)	1.462 (1.092–1.962)*	1.352 (1.000–1.831)	1.260 (0.925–1.718)	1.583 (0.943–2.600)	1.480 (0.875–2.449)	1.460 (0.847–2.463)
SCC	1.012 (0.868–1.179)	1.026 (0.878–1.200)	1.021 (0.872–1.196)	1.329 (1.139–1.550)***	1.327 (1.134–1.553)***	1.259 (1.074–1.477)**	1.576 (1.268–1.972)***	1.550 (1.245–1.944)***	1.491 (1.193–1.875)***
MCR	1.826 (1.354–2.471)***	1.868 (1.371–2.554)***	1.739 (1.258–2.411)***	1.891 (1.382–2.603)***	1.885 (1.360–2.628)***	1.727 (1.236–2.425)**	2.173 (1.656–2.861)***	2.061 (1.564–2.724)***	1.924 (1.444–2.571)***

Model 1:Univariate logistic regression analysis

Model 2:Adjusted for age, sex, level of education, marital status

Model 3:Adjusted for all covariates from Model 2, along with smoking status, drinking status, systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, body mass index (BMI), and chronic disease conditions

* $p<.05$, ** $p<.01$, *** $p<.001$

group. This result aligns with prior multi-centre studies, which, through their broader geographic scope and extended follow-up periods, effectively mitigated biases related to cultural differences and short-term fluctuations [12]. These factors further support the generalizability of MCR as a reliable predictor of falls across diverse ageing populations. Emerging evidence suggests that MCR is associated with an increased risk of falls and a heightened risk of recurrent falls and post-fall hip fractures [14]. We observed a consistent association between MCR and multiple falls across ELSA and HRS. These contrasts with prior studies that reported inconsistent results, potentially due to methodological differences. For instance, some studies relied on single-centre designs with shorter follow-ups [12], potentially underestimating the long-term risk of recurrent falls.

Furthermore, individuals who have experienced falls may develop a fear of falling, which can lead to reduced physical activity and further exacerbate declines in motor function [25, 26]. Additionally, falls may result in social isolation, which can further worsen cognitive and motor decline [26–28]. However, there is limited research on the specific association between fall-related injuries. It may be because most studies focus on the frequency of falls and changes in cognitive function rather than the specific injury situation after a fall [29]; the severity of fall-related injuries warrants further investigation.

MCR, a pre-dementia syndrome, is characterized by SCC and slow gait. Previous studies independently contribute to an increased risk of falls. Slow gait is associated with a 30% increased risk of falls, while cognitive complaints increase this risk by 25% [12]. The simplicity of MCR makes it an attractive, quick, and cost-effective screening tool for falls in clinical settings, offering an alternative to slow gait speed, which is commonly recommended as a fall risk screening test [30]. Current evidence consistently demonstrates that slow gait is a significant predictor of falls in older adults [31]. This association extends beyond immediate fall risk, encompassing broader implications for functional dependence and overall mortality [32]. Interestingly, our investigation failed to establish a significant correlation between slow gait and fall incidents. The findings of our study showed that SCC, but not slow gait, increased the risk of future falls, which was inconsistent with some existing studies [14]. This finding challenges the conventional view of gait speed as a standalone predictor. Some studies suggest that the neuropathological basis of MCR includes damage to the prefrontal and motor cortex, which may affect motor and cognitive function. In addition, SCC may be a sign of early cognitive decline, which may affect the risk of falls before slow gait. Overall, MCR, which synthesizes both SCC and slow gait, demonstrated superior predictive stability and enhanced prognostic value for fall risk assessment [33].

The mechanisms underlying the increased fall risk in MCR involve physiological, cognitive, and psychological factors. Previous studies showed that MCR involves a physical decline in muscle strength, particularly in the lower limbs, which can impair balance and walking stability [34, 35]. Additionally, balance issues arise from degenerative changes in the nervous system that affect vision, vestibular sensation, and proprioception. At the same time, people with MCR may experience balance issues due to degenerative changes in the nervous system [34]. MCR greatly impacts executive function, attention, and processing speed, which are crucial for maintaining balance and preventing falls [36]. Glumac et al. (2017) [37] showed that inflammatory responses are crucial for cognitive decline, especially in motor function. In

Table 4 Logistic regression analysis of future falls (dependent variable) and MCR (independent variable) after deleting the people who have fallen down in recent 2 years before baseline

Variables	ELSA			HRS			CHARLS		
	Model1 OR[95%CI]	Model2 OR[95%CI]	Model3 OR[95%CI]	Model1 OR[95%CI]	Model2 OR[95%CI]	Model3 OR[95%CI]	Model1 OR[95%CI]	Model2 OR[95%CI]	Model3 OR[95%CI]
Non-MCR	1	1	1	1	1	1	1	1	1
MCR	2.452 (1.260–5.249)*	2.161 (1.092–4.682)*	2.056 (1.012–4.550)*	1.732 (1.243–2.431)**	1.760 (1.253–2.489)**	1.583 (1.120–2.254)**	1.427 (1.136–1.786)**	1.367 (1.085–1.714)**	1.294 (1.023–1.630)*

Model 1:Univariate logistic regression analysis

Model 2:Adjusted for age, sex, level of education, marital status

Model 3:Adjusted for all covariates from Model 2, along with smoking status, drinking status, systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, body mass index (BMI), and chronic disease conditions

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 5 Cox proportional hazards regression analysis of future falls (dependent variable) and MCR (independent variable)

Variables	ELSA			HRS			CHARLS		
	Model1 HR[95%CI]	Model2 HR[95%CI]	Model3 HR[95%CI]	Model1 HR[95%CI]	Model2 HR[95%CI]	Model3 HR[95%CI]	Model1 HR[95%CI]	Model2 HR[95%CI]	Model3 HR[95%CI]
Non-MCR	1	1	1	1	1	1	1	1	1
MCR	1.641 (1.205–2.235)**	1.477 (1.075–2.030)*	1.414 (1.018–1.966)*	1.619 (1.307–2.004)***	1.600 (1.289–1.985)***	1.442 (1.159–1.794)**	1.377 (1.142–1.661)***	1.315 (1.089–1.588)**	1.251 (1.035–1.513)*

Model 1:Univariable Cox proportional hazards regression analysis

Model 2:Adjusted for age, sex, level of education, marital status

Model 3: Adjusted for all covariates from Model 2, along with smoking status, drinking status, systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, body mass index (BMI), and chronic disease conditions

* $p<.05$, ** $p<.01$, *** $p<.001$

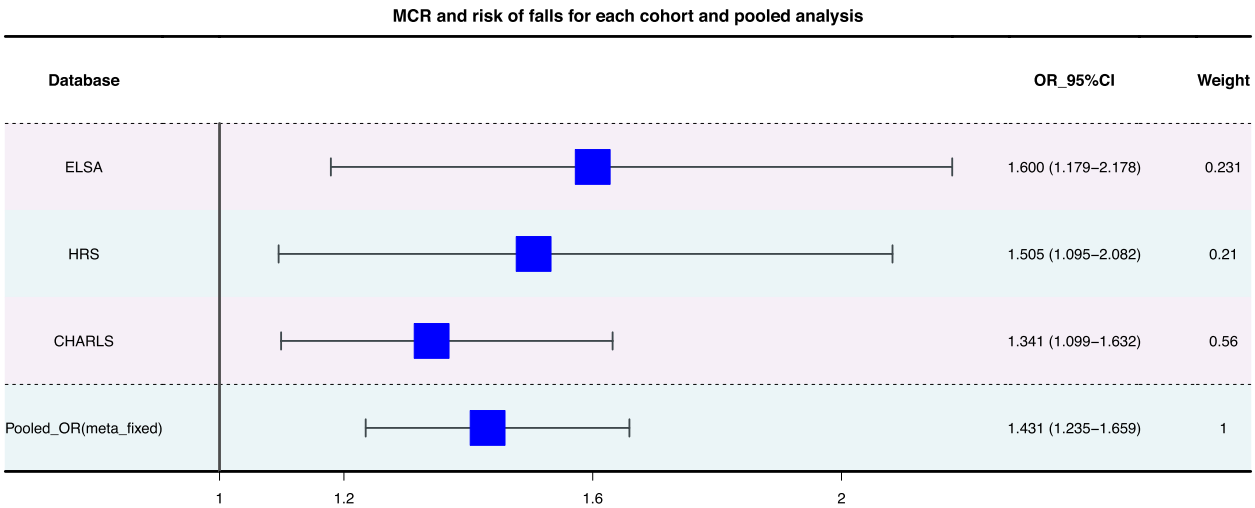

Fig. 3 Forest plot of MCR and risk of falls for each cohort and pooled analysis

MCR patients, these responses may cause both cognitive and motor impairments, increasing fall risk. Cognitive impairment can exacerbate gait disturbances, creating a vicious cycle that increases the risk of falls [34]. Psychological factors such as anxiety and depression, common in older adults with MCR, can further increase fall risk [38, 39]. Fear of falling, a manifestation of anxiety, can lead to avoidance behaviours and reduced physical

activity, while depressive symptoms are associated with reduced executive function and muscle strength [40].

To the best of our knowledge, this is the first prospective study that investigates MCR and its components as predictors of various types of falls among older adults in the US, UK and China, based on large, nationally representative cohorts. Our findings reveal relatively stable and consistent associations across populations. These results underscore the importance of early identification and intervention for individuals with MCR, with evidence suggesting that moderate-intensity physical activity [33] and dual-task training [41] may effectively enhance both gait performance and cognitive function [42], thereby reducing fall risk.

Strengths and limitations

A key strength of this study is the inclusion of three large-scale prospective cohorts representing diverse ethnic and national populations, which enhances statistical power and ensures broad demographic representation. The consistency of findings across these cohorts strengthens the external validity of our results and supports their potential clinical applicability in varied settings. However, several limitations should be noted. First, although each cohort had a follow-up period of four years, longer-term follow-up is necessary to more comprehensively understand the trajectories and risk factors associated with falls and MCR. Second, the reliance on self-reported fall data, while pragmatic for large-scale epidemiological studies, may introduce recall bias. Third, the assessment methods for SCC and slow gait lack standardization across studies, which complicates comparisons and may affect the accuracy of MCR prevalence estimates. In our study, SCC was measured using a self-rated memory question. In contrast, other studies have used memory-related items from various scales, such as the three-item recall test, the Mini-Mental State Examination, and the Geriatric Depression Scale [15, 29]. Similarly, definitions of slow gait varied: we classified it using age- and sex-specific means and standard deviations of gait speed, while other studies applied fixed cutoff values [14].

Conclusion

In this large-scale prospective study, we identified an increased risk of falls among individuals with MCR. While MCR emerged as a significant predictor, slow gait alone did not demonstrate independent predictive value, and SCC warrant further investigation to clarify their specific applications. These findings highlight the potential of MCR as a clinically useful screening tool that integrates cognitive and motor parameters, thereby improving fall risk identification in the older adult population.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-06062-w.

Supplementary Material 1: Supplementary Fig. 1. Subgroup analysis of MCR and risk of falls in ELSA.

Supplementary Material 2: Supplementary Fig. 2. Subgroup analysis of MCR and risk of falls in HRS.

Supplementary Material 3: Supplementary Fig. 3. Subgroup analysis of MCR and risk of falls in CHARLS.

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Authors' contributions

JL and DY designed the study. JL and QH managed and analyzed the data. JL prepared the first draft. QW prepared all figures. WS, and WS reviewed and edited the manuscript, with comments from WS and QH. All authors were involved in revising the paper and gave final approval of the submitted versions.

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Data availability

The datasets generated and analyzed during the current study are available from the websites of ELSA at https://www.elsa-project.ac.uk/, HRS at https://hrs.isr.umich.edu/, and CHARLS at https://charls.pku.edu.cn/en.

Declarations

Ethics approval and consent to participate

Since we used secondary-analysis data from public datasets, including ELSA (approved by National Research and Ethics Service Committee South Central-Berkshire), HRS (approved by National Institute on Aging and the Social Security Administration, NIA U01AG009740), and CHARLS (approved by the Ethical Review Committee of Perking University, IRB00001052-11015). So the detailed ethical approval could be found on respective origin surveys. Meanwhile, written informed consent was also obtained from any participant. Additionally, our study adhered to the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Jónsdóttir HL, Ruthig JC. A longitudinal study of the negative impact of falls on health, well-being, and survival in later life: the protective role of perceived control. Aging Ment Health. 2021;25(4):742–8. https://doi.org/10.1080/13607863.2020.1725736.
2. World Health Organization. Falls. World Health Organization; 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/falls.
3. Burns E, Kakara R. Deaths from falls among persons aged ≥65 years - United States, 2007–2016. MMWR Morb Mortal Wkly Rep. 2018;67(18):509–14. https://doi.org/10.15585/mmwr.mm6718a1.
4. Centers for Disease Control and Prevention. National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS) [online]. 2005. Available from: www.cdc.gov/injury/wisqars.
5. Stevens JA, Mahoney JE, Ehrenreich H. Circumstances and outcomes of falls among high-risk community-dwelling older adults. Inj Epidemiol. 2014;1(1):5. https://doi.org/10.1186/2197-1714-1-5.
6. Park SH. Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. Aging Clin Exp Res. 2018;30(1):1–16. https://doi.org/10.1007/s40520-017-0749-0.
7. Stevens JA, Corso PS, Finkelstein EA, Miller TR. The costs of fatal and non-fatal falls among older adults. Inj Prev. 2006;12(5):290–5. https://doi.org/10.1136/ip.2005.011015.
8. Strini V, Schiavolin R, Prendin A. Fall risk assessment scales: a systematic literature review. Nurs Rep. 2021;11(2):430–43. https://doi.org/10.3390/nursrep11020041.
9. Muir SW, Gopaul K, Montero Odasso MM. The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. Age Ageing. 2012;41(3):299–308. https://doi.org/10.1093/ageing/afs012.
10. Allali G, Launay CP, Blumen HM, Callisaya ML, De Cock AM, Kressig RW, Srikanth V, Steinmetz JP, Verghese J, Beauchet O, Biomathics Consortium. Falls, cognitive impairment, and gait performance: results from the GOOD initiative. J Am Med Dir Assoc. 2017;18(4):335–40. https://doi.org/10.1016/j.jamda.2016.10.008.
11. Xu W, Bai A, Liang Y, Lin Z. Motoric cognitive risk syndrome and the risk of incident dementia: a systematic review and meta-analysis of cohort studies. Gerontology. 2024;70(5):479–90. https://doi.org/10.1159/000535082.
12 Callisaya ML, Ayers E, Barzilai N, Ferrucci L, Guralnik JM, Lipton RB, et al. Motoric cognitive risk syndrome and falls risk: a multi-center study. Montero-Odasso M, editor. JAD. 2016;53(3):1043–52. https://doi.org/10.3233/jad-160230.
13. Lu W, Liu B, Lv M, Tu J, Kang Z, Hu R, et al. Association between motoric cognitive risk syndrome and future falls among Chinese community-dwelling elderly: a nationwide cohort study. Brain Behav. 2023;13(7):e3044. https://doi.org/10.1002/brb3.3044.
14. Beauchet O, Sekhon H, Schott AM, Rolland Y, Muir-Hunter S, Markle-Reid M, et al. Motoric cognitive risk syndrome and risk for falls, their recurrence, and postfall fractures: results from a prospective observational population-based cohort study. J Am Med Dir Assoc. 2019;20(10):1268–73. https://doi.org/10.1016/j.jamda.2019.04.021.
15. Lord S, Moyes S, Teh R, Port W, Muru-Lanning M, Bacon CJ, et al. Gait, cognition and falls over 5 years, and motoric cognitive risk in New Zealand octogenarians: Te Puāwaitanga o Nga Tapuwae Kia Ora Tonu, LiLACS NZ. BMC Geriatr. 2020;20(1):43. https://doi.org/10.1186/s12877-020-1420-8.
16. Verghese J, Wang C, Lipton RB, Holtzer R. Motoric cognitive risk syndrome and the risk of dementia. J Gerontol A Biol Sci Med Sci. 2013;68(4):412–8. https://doi.org/10.1093/gerona/gls191.
17. Liu J, Cui K, Chen Q, Li Z, Fu J, Gong X, et al. Association of walking speed with cognitive function in Chinese older adults: a nationally representative cohort study. Front Aging Neurosci. 2022;14:1003896. https://doi.org/10.3389/fnagi.2022.1003896.
18. Ko J, Ha J, Lee JJ, Jin S, Lee J, Baek MS, et al. Reliability and validity of the Subjective Cognitive Complaints Questionnaire for Parkinson's Disease (SCCQ-PD). J Clin Neurol. 2022;18(2):171–8. https://doi.org/10.3988/jcn.2022.18.2.171.
19. Bu F, Abell J, Zaninotto P, Fancourt D. A longitudinal analysis of loneliness, social isolation and falls amongst older people in England. Sci Rep. 2020;10(1):20064. https://doi.org/10.1038/s41598-020-77104-z.
20. Fundenberger H, Stephan Y, Terracciano A, Dupré C, Bongue B, Hupin D, et al. Subjective age and falls in older age: evidence from two longitudinal cohorts. J Gerontol B Psychol Sci Soc Sci. 2022;77(10):1814–9. https://doi.org/10.1093/geronb/gbac094.
21. Tian Y, Zhou X, Jiang Y, Pan Y, Liu X, Gu X. Bidirectional association between falls and multimorbidity in middle-aged and elderly Chinese adults: a national longitudinal study. Sci Rep. 2024;14(1):9109. https://doi.org/10.1038/s41598-024-59865-z.
22. Chan Y, Walmsley RP. Learning and understanding the Kruskal-Wallis one-way analysis-of-variance-by-ranks test for differences among three or more independent groups. Phys Ther. 1997;77(12):1755–62. https://doi.org/10.1093/ptj/77.12.1755.
23. Larson MG. Analysis of variance. Circulation. 2008;117(1):115–21. https://doi.org/10.1161/CIRCULATIONAHA.107.654335.
24. Yuan JL, Zhao RX, Ma YJ, Li XD, Zhou XM, Wang XF, et al. Prevalence/potential risk factors for motoric cognitive risk and its relationship to falls in elderly Chinese people: a cross-sectional study. Eur J Neurol. 2021;28(8):2680–7. https://doi.org/10.1111/ene.14884.
25. Verghese J, Ayers E, Barzilai N, Bennett DA, Buchman AS, Holtzer R, et al. Motoric cognitive risk syndrome: multicenter incidence study. Neurology. 2014;83(24):2278–84. https://doi.org/10.1212/WNL.0000000000001084.
26. Jayakody O, Blumen HM, Breslin M, Ayers E, Lipton RB, Verghese J, et al. Longitudinal associations between falls and future risk of cognitive decline, the motoric cognitive risk syndrome and dementia: the Einstein ageing study. Age Ageing. 2022;51(3):afac058. https://doi.org/10.1093/ageing/afac058.
27. Choi NG, Marti CN, Choi BY, Kunik MM. Recurrent falls over three years among older adults age 70+: associations with physical and mental health status, exercise, and hospital stay. J Appl Gerontol. 2023;42(5):1089–100. https://doi.org/10.1177/07334648221150884.
28. Li Y, Hou L, Zhao H, Xie R, Yi Y, Ding X. Risk factors for falls among community-dwelling older adults: a systematic review and meta-analysis. Front Med (Lausanne). 2023;6(9):1019094. https://doi.org/10.3389/fmed.2022.1019094.
29. Shim H, Kim M, Won CW. Motoric cognitive risk syndrome using three-item recall test and its associations with fall-related outcomes: the Korean frailty and aging cohort study. Int J Environ Res Public Health. 2020. https://doi.org/10.3390/ijerph17103364.
30. Montero-Odasso M, Schapira M, Soriano ER, Varela M, Kaplan R, Camera LA, et al. Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. J Gerontol A Biol Sci Med Sci. 2005;60(10):1304–9. https://doi.org/10.1093/gerona/60.10.1304.
31. Figgins E, Pieruccini-Faria F, Speechley M, Montero-Odasso M. Potentially modifiable risk factors for slow gait in community-dwelling older adults: a systematic review. Ageing Res Rev. 2021;66:101253. https://doi.org/10.1016/j.arr.2020.101253.
32. Beck Jepsen D, Robinson K, Ogliari G, Montero-Odasso M, Kamkar N, Ryg J, et al. Predicting falls in older adults: an umbrella review of instruments assessing gait, balance, and functional mobility. BMC Geriatr. 2022;22(1):615. https://doi.org/10.1186/s12877-022-03271-5.
33. Xiang K, Liu Y, Sun L. Motoric cognitive risk syndrome: symptoms, pathology, diagnosis, and recovery. Front Aging Neurosci. 2021;13:728799. https://doi.org/10.3389/fnagi.2021.728799.
34. Casey CM, Caulley J, Phelan EA. The intersection of falls and dementia in primary care: evaluation and management considerations. Med Clin North Am. 2020;104(5):791–806. https://doi.org/10.1016/j.mcna.2020.06.003.
35. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle weakness and falls in older adults: a systematic review and meta-analysis. J Am Geriatr Soc. 2004;52(7):1121–9. https://doi.org/10.1111/j.1532-5415.2004.52310.x.
36. Amboni M, Barone P, Hausdorff JM. Cognitive contributions to gait and falls: evidence and implications. Mov Disord. 2013;28(11):1520–33. https://doi.org/10.1002/mds.25674.
37. An Y, Yang Y, Wang A, Li Y, Zhang Q, Cheung T, et al. Prevalence of depression and its impact on quality of life among frontline nurses in emergency departments during the COVID-19 outbreak. J Affect Disord. 2020;1(276):312–5. https://doi.org/10.1016/j.jad.2020.06.047.
38. Jacob L, Kostev K, Shin JI, Smith L, Oh H, Abduljabbar AS, et al. Falls increase the risk for incident anxiety and depressive symptoms among adults aged ≥50 years: an analysis of the Irish longitudinal study on ageing. Arch Gerontol Geriatr. 2023;114:105098. https://doi.org/10.1016/j.archger.2023.105098.

39. Iaboni A, Flint AJ. The complex interplay of depression and falls in older adults: a clinical review. Am J Geriatr Psychiatry. 2013;21(5):484–92. https://doi.org/10.1016/j.jagp.2013.01.008.
40. Jardim NYV, Bento-Torres NVO, Costa VO, Carvalho JPR, Pontes HTS, Tomás AM, Sosthenes MCK, Erickson KI, Bento-Torres J, Diniz CWP. Dual-task exercise to improve cognition and functional capacity of healthy older adults. Front Aging Neurosci. 2021;16(13):589299. https://doi.org/10.3389/fnagi.2021.589299.
41. Peng H, Yao N, Song YP, Huang L, Chen HB, Jiang Y, Chen QG. Motoric cognitive risk syndrome: a review of fall risk assessment and management strategies. World J Psychiatry. 2025;15(4):101800. https://doi.org/10.5498/wjp.v15.i4.101800.
42. Al-Yahya E, Dawes H, Smith L, Dennis A, Howells K, Cockburn J. Cognitive motor interference while walking: a systematic review and meta-analysis. Neurosci Biobehav Rev. 2011;35(3):715–28. https://doi.org/10.1016/j.neubiorev.2010.08.008.

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