Postprint: Development of a Fall Risk Assessment Model for Older Adults

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Abstract

Objective To explore the construction of a comprehensive assessment model for fall risk applicable to Chinese elderly populations. Methods Fall risk factors and their corresponding odds ratios (OR values) were screened through meta-analysis re-evaluation combined with structured expert consultation to establish a logistic regression-based comprehensive assessment model. Results The model ultimately incorporated 32 indicators: age, history of falls, physical exercise, use of walking aids, gait abnormalities, balance abnormalities, sleep disorders, cognitive impairment, frailty, urinary/fecal incontinence, dizziness/vertigo, visual impairment, hearing impairment, lower limb arthritis, history of stroke, diabetes mellitus, orthostatic hypotension, Parkinson's disease, dementia, anemia, arrhythmia, depression, foot problems, antipsychotic medications, antidepressants, hypnotic-sedative drugs, antiepileptic drugs, opioid analgesics, loop diuretics, cardiac glycosides, hypoglycemic agents, and laxatives. Conclusion This study established a fall risk assessment model for Chinese elderly based on meta-analysis and expert opinion, effectively circumventing the issue of insufficient sample size. Grounded in evidence-based medicine, the model provides a foundation and guidance for screening high-risk populations and implementing preventive interventions.

Full Text

Preamble

Construction of a Risk Assessment Model for Falls in the Elderly

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Abstract

Objective: To develop a comprehensive fall risk assessment model suitable for elderly individuals in China.
Methods: We conducted a meta-analysis reappraisal combined with structured expert consultation to identify fall risk factors and their odds ratios (ORs) for inclusion in a logistic regression-based comprehensive assessment model.
Results: The final model included 32 indicators: age, history of falls, exercise, use of walking aids, abnormal gait, abnormal balance, sleep disorders, cognitive impairment, frailty, urinary/fecal incontinence, dizziness/vertigo, visual impairment, hearing impairment, lower extremity arthritis, history of stroke, diabetes, orthostatic hypotension, Parkinson's disease, dementia, anemia, arrhythmia, depression, foot problems, antipsychotics, antidepressants, hypnotic-sedative medications, antiepileptic drugs, opioid analgesics, loop diuretics, cardiac glycosides, hypoglycemic agents, and laxatives.
Conclusion: Based on meta-analysis evidence and expert opinion, this study established a fall risk assessment model for Chinese elderly individuals that effectively avoids problems associated with small sample sizes. Grounded in evidence-based medicine, the model provides a foundation and guidance for screening high-risk populations and implementing interventions.

Keywords: falls; elderly; risk assessment; model construction

Introduction

Falls among older adults represent a global public health concern, with approximately one-third of individuals aged 65 and older experiencing a fall each year, and about 10% sustaining fall-related injuries. Falls not only compromise physical and mental health, reduce quality of life, and decrease life expectancy, but also impose substantial economic burdens on families and society. China faces an increasingly severe challenge due to its large elderly population base and rapidly accelerating aging trends. Disease risk assessment models, also known as risk prediction models, quantify relationships between physiological conditions, living environments, and other risk factors with health outcomes to predict an individual's probability of developing a specific condition within a defined timeframe. This methodology has been widely applied in chronic disease prevention; however, no consensus exists regarding an optimal fall risk assessment model. Therefore, this study systematically reviewed domestic and international meta-analyses to establish a fall risk assessment model for Chinese elderly populations, thereby enabling prediction of fall risk in this demographic.

1. Materials and Methods

1.1 Literature Search and Inclusion Criteria

We systematically searched Cochrane Library, Web of Science, PubMed, Embase, CNKI, WanFang Database, Chinese Biomedical Abstract Database, and

VIP from inception to [date]. The search strategy combined subject headings and free-text terms. Chinese search terms included: “elderly,” “falls,” “risk factors,” “influencing factors,” “related factors,” “Meta-analysis,” and “systematic review.” English search terms included: “the elderly,” “aged,” “old people,” ”fall*,” “Meta-analysis,” and “systematic review.” We included meta-analyses examining fall risk factors in individuals aged 60 years or older, published in Chinese or English. Studies focusing on special diseases (e.g., Parkinson’s disease) were excluded because this study conceptualizes disease itself as a risk factor. Environmental and external factors were not considered in this model.

1.2 Data Extraction and Quality Assessment

Two researchers independently extracted data from included studies and cross-checked results. Extracted information comprised first author, publication year, risk factors, number of included studies, sample size, effect model, effect size with 95% confidence interval, and heterogeneity. Methodological quality was independently assessed using the AMSTAR 2 tool. Disagreements were resolved through discussion or consultation with a third party.

1.3 Structured Expert Consultation

A panel of 15 experts with backgrounds in evidence-based medicine and clinical practice was convened. Each expert scored potential risk factors derived from meta-analyses based on professional judgment combined with the reappraisal results. The scoring system used: 1 = disagree, 2 = uncertain, 3 = agree. A discrete degree (standard deviation/mean) >0.25 indicated controversial items requiring further discussion. After each round, the expert panel interpreted scoring results and evidence understanding. Indicators with high scores ($ $2.5) and low discrete degree (<0.25) were included in the model. Three rounds of consultation were conducted until consensus was achieved (discrete degree <0.25). The expert panel selected appropriate odds ratios (OR), risk ratios (RR), or hazard ratios (HR) for included indicators.

1.4 Logistic Regression Model

Based on logistic regression, we established the fall risk assessment model:

$$Logit(P) = \ln\left(\frac{P}{1-P}\right) = \alpha + \beta_{1x}1 + \beta_{2x}2 + \cdots + \beta_{mx}m$$

where P represents an individual’s probability of falling, $x_1, \ldots, x_m$ denote m fall risk factors, and β represents regression coefficients convertible from pooled risk estimates (OR/RR/HR). The constant term α is estimated from local fall incidence rates:

$$\alpha = \ln\left(\frac{P}{1-P}\right) - (\beta_1\bar{x}_1 + \beta_2\bar{x}_2 + \cdots + \beta_m\bar{x}_m)$$

where P is the fall incidence rate and $\bar{x}_1, \bar{x}_2, \ldots, \bar{x}_m$ represent average exposure levels of each risk factor in a population. However, since exposure rates for individual risk factors are often unavailable, the α correction can be omitted for practicality, yielding:

$$\alpha = \ln\left(\frac{P}{1-P}\right)$$

While this optimization enhances model applicability, it may overestimate predicted risk when certain risk factor exposure rates are exceptionally high.

2. Results

2.1 Fall Risk Factors in the Elderly

Comprehensive retrieval identified 66 meta-analyses on fall risk factors. The search process is illustrated in [Figure 1: see original paper]. Retrieved risk factors were categorized as follows:

- **General factors:** age, gender, fall history, nutritional status
- **Lifestyle factors:** living alone, exercise, use of walking aids, alcohol consumption, inappropriate footwear, wandering
- **Psychological factors:** fear of falling, self-perceived health status
- **Physical function factors:** fatigue, frailty, abnormal gait, abnormal balance, mobility difficulty, ADL dependence, dizziness/vertigo, visual/hearing impairment, cognitive impairment, urinary/fecal incontinence, pain, sleep disorders, muscle weakness, disability, sensory impairment
- **Disease factors:** sarcopenia, rheumatism/arthritis, hypertension, stroke, dementia, diabetes, orthostatic hypotension, arrhythmia, Parkinson's disease, anemia, depression, foot problems, eye disease, cancer
- **Medication factors:** antipsychotics, antidepressants, sedative-hypnotics, antiepileptic drugs, opioids, loop diuretics, cardiac glycosides, statins, hypoglycemic agents, laxatives, proton pump inhibitors (PPIs)

Methodological quality assessment results using AMSTAR 2 are presented in .

2.2 Structured Expert Consultation Results

After the first consultation round, experts recommended merging frailty and sarcopenia, as frailty assessment encompasses fatigue and muscle strength measurement. The "disability" indicator proved controversial—while lower limb disability clearly affects fall risk, the impact of upper limb disability remains unclear. "Foot disease" was revised to "foot problems" to encompass foot deformities, sensory abnormalities, and related conditions. "Rheumatism/arthritis" was refined to "lower extremity arthritis." Following three rounds of structured expert consultation, 32 indicators with mean scores $ $2.5 were included. Detailed results appear in . The final model indicators and their assigned values are shown in .

2.3 Establishment of the Fall Risk Assessment Model

Based on literature review and expert consultation, the final model incorporating 32 indicators was established as:

$$Logit(P) = -4.61+0.61X_1+1.08X_2+0.40X_3+0.31X_4+0.82X_5+0.39X_6+0.31X_7+0.36X_8+0.28X_9+0.55X_{10}+0.$$

The variables respectively represent: age, fall history, exercise/use of walking aids, frailty, abnormal gait, abnormal balance, dizziness/vertigo, sleep disorder, visual impairment, hearing impairment, cognitive impairment, urinary/fecal incontinence, lower extremity arthritis, diabetes, stroke history, dementia, orthostatic hypotension, arrhythmia, Parkinson's disease, anemia, depression, foot problems, antipsychotics, antidepressants, hypnotic-sedatives, antiepileptic drugs, opioid analgesics, loop diuretics, cardiac glycosides, hypoglycemic agents, and laxatives.

2.4 Model Validation

Using MedCalc software for sample size calculation (α=0.05, β=0.2, expected minimum AUC=0.85), the required minimum sample size was 100 (50 cases and 50 controls). Convenience sampling was employed at a tertiary hospital in Beijing, comprising 50 elderly patients who had experienced falls and 50 who had not. ROC curve analysis based on validation data yielded an AUC of 0.958 (95%CI: 0.915-1.000, P<0.001), as shown in [Figure 2: see original paper]. At the optimal cutoff point, model sensitivity and specificity both exceeded 90%.

3. Discussion

3.1 Selection of Risk Assessment Model Indicators

This study adhered to principles of comprehensiveness, convenience, and strong association when selecting risk factors. Among general factors, age and fall history were included due to well-established associations with increased fall risk. Advanced age correlates with physiological decline and reduced environmental responsiveness, while individuals with prior falls demonstrate substantially higher recurrence rates, potentially related to psychological changes or post-fall trauma and altered mobility.

Lifestyle factors incorporated exercise and walking aid use. Multiple studies indicate that walking aid users face elevated fall risk, likely attributable to underlying balance impairment or lower extremity weakness that necessitates device use. Conversely, regular exercise serves as a protective factor, with active elderly individuals demonstrating reduced fall risk compared to sedentary counterparts.

Physical function factors included frailty, gait and balance abnormalities, dizziness/vertigo, sensory impairments, cognitive dysfunction, sleep disorders, and urinary/fecal incontinence—all well-documented fall risk factors. The mechanism linking sleep disorders to falls remains incompletely understood but may involve sleep-related sarcopenia, impaired neurorepair, reduced cognitive function, and attention deficits that compromise environmental responsiveness. Hearing impairment independently increases fall risk, with recent meta-analyses indicating a 2.39-fold higher risk among hearing-impaired elders. Urinary/fecal incontinence elevates fall risk through frequent toileting needs and nocturia, while cognitive impairment correlates with fall risk through neuroanatomical changes such as cerebral white matter lesion volume.

Disease-related factors encompassed lower extremity arthritis, diabetes, stroke history, dementia, orthostatic hypotension, arrhythmia, Parkinson's disease, foot problems, anemia, and depression. Chronic diseases significantly impact physiological and psychological health, thereby increasing fall risk. For instance, lower extremity arthritis compromises mobility and postural stability, while Parkinson's disease causes rigidity, bradykinesia, and pathological gait. Foot problems including pain, sensory abnormalities, and deformities affect standing balance and center of gravity. Depression correlates with reduced physical activity, fear of falling, and impaired balance and mobility.

Medication factors included central nervous system agents (antipsychotics, antidepressants, hypnotic-sedatives, antiepileptics, opioids), cardiovascular drugs (loop diuretics, cardiac glycosides), and other medications (hypoglycemic agents, laxatives). These medications increase fall risk through adverse effects such as sedation, orthostatic hypotension, cognitive impairment, ataxia, and hypoglycemia.

Excluded factors included nutritional status, alcohol consumption, inappropriate footwear, fear of falling, self-perceived health, wandering, pain, gender, and living alone. These exclusions were based on: (1) strong subjectivity hindering standardized assessment; (2) dose-dependent relationships (e.g., alcohol); (3) confounding with included variables (e.g., fear of falling correlates with fall history and depression); (4) insufficient evidence (e.g., statins, PPIs); or (5) non-significant associations in recent literature (e.g., hypertension).

3.2 Practical Guidance from the Risk Assessment Model

Based on meta-analysis evidence and expert consultation, this model enables calculation of community fall risk. Practical application requires knowledge of local fall incidence rates and exposure rates for each risk factor. When precise exposure rates are unavailable, the simplified formula ignoring α correction can be used, enhancing model utility. The optimized logistic regression model achieved an AUC of 0.958 (P<0.001), with sensitivity and specificity exceeding 90%, demonstrating high accuracy and predictive efficacy suitable for Chinese elderly populations. This enables identification of high-risk individuals for targeted intervention programs.

3.3 Individual Fall Risk Prediction Method

Assuming a regional fall rate of 20%, individual risk calculation proceeds as follows: Consider a 70-year-old without fall history or walking aid use, who does not exercise regularly, has hearing impairment, knee osteoarthritis, and diabetes, and takes hypnotic and hypoglycemic medications but no other drugs. Using the model:

Constant term: α = ln(0.2/(1-0.2)) = -1.39

Combining risk factors:

$$Logit(P) = -1.39 + 0.36 \times 1 + 0.31 \times 1 + 0.55 \times 1 + 0.47 \times 1 + 0.47 \times 1 = 0.88$$

$$P = \frac{e^{0.88}}{1 + e^{0.88}} = 0.71$$

This indicates a 71% fall risk for this individual—3.55 times higher than the general elderly population—enabling targeted preventive interventions.

3.4 Limitations

This study has several limitations. First, time constraints precluded prospective cohort validation of model efficacy. Second, the model considers only individual factors, excluding environmental influences. Future research should incorporate updated high-quality studies to refine model indicators, employ cohort studies for validation, and integrate environmental factors to develop more comprehensive fall risk assessment models tailored to Chinese elderly populations.

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Note: Figure translations are in progress. See original paper for figures.