A prospective cohort study of the risk factors for new falls and fragility fractures in self-caring elderly patients aged 80 years and over

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Abstract

Background: This study aimed to prospectively analyze the risk factors for new falls and fragility fractures in self-caring elderly patients and to find suitable evaluation tools for community screening and follow-up interventions.

Methods: A total of 300 participants (187 male and 113 female), aged 80 or above and capable of caring for themselves, were enrolled in this study and observed for a period of 12 months. Their medical histories were collected, various indicators were measured, and the risk factors for new falls and fragility fractures were analyzed.

Results: A total of 290 participants were included in the statistical analysis. Eighty-seven participants (30%) had new falls. The incidence was negatively correlated with the activities of daily living (ADL, represented by the Barthel Index) score (P=0.008) but was positively correlated with the timed up-and-go (TUG) test score (P=0.021). The results also revealed that 33 fragility fractures occurred in 29 patients (10.0%), which was positively correlated with new falls (P=0.000). New fragility fractures were negatively correlated with the bone mineral density (BMD) of the lumbar vertebrae (P=0.012) and walking speed (P=0.000).

Conclusion: TUG, walking speed, the ADL score, and the fall risk assessment scale can simply and effectively assess the risk of new falls and fragility fractures in the elderly population, and their use should be widely implemented in the community.

Keywords: Falls, Fragility fractures, Aged 80 years and over, Timed up-and-go (TUG) test, Walking speed

Background

The type of fall this study is looking at is one in which a person loses their balance when they are standing or upright and, as a result, they end up on the ground or at a lower level. Other types of fall such as those caused by an act of violence, loss of consciousness, hemiplegia or epileptic seizure are not included in this study [1]. For the elderly population, a fall is an independent risk factor of fragility fracture. In other words, its consequences can be serious [1]. Falls in the elderly population are the result of the combined action of internal factors, such as the state of their health, and external factors, such as their environment [2]. The elderly are subject to the natural deterioration of tissue structure and the physiological function of various systems, which can result, in particular, in lower limb weakness. This is an important risk factor for the occurrence of falls in the elderly. Gait disorder, walking instability, and balance impairment are caused by a decline in the structure and functioning of the central nervous system and peripheral
nerves, which is also closely related to diseases such as spinal stenosis and osteoarthritis [2]. The impairment of vision, hearing, muscle strength, and response speed will also reduce the ability of elderly patients to respond to stimuli, and they will also experience the loss of their self-protection ability, further increasing the risk of falls and injury [3]. Multi-system complications of the elderly, such as cardiovascular and cerebrovascular diseases, diabetes, mental disorders, cataracts, hearing impairment, and the long-term use of a variety of drugs are also risk factors for falls in this population [3]. In turn, fall-induced injuries increase the risk of delirium, cognitive decline and disability in the elderly.

Falling has a high incidence rate in the elderly population nowadays, and it has become a public health problem attracting great concern. Studies have revealed that 40–50% of the elderly aged ≥80, living in the community, fall at least once a year [2, 3] and that 90% of fragility fractures in patients with osteoporosis are caused by falls [4]. An osteoporotic fracture, which is regarded as a low-energy fracture [5], is seen as a non-traumatic or slight traumatic fracture and is a clear sign of the reduction in bone strength, and, thus, an eventual consequence of osteoporosis. The common sites of such fractures are the spine, hip, and distal forearm. Fragility fractures result in a heavy economic burden on patients and their families, as well as on society as a whole. As the population structure changes, and life expectancy increases, this burden is expected to increase in the future [6]. China has officially been an aging society since 2000, and it is estimated that the number of osteoporosis patients in China will have increased from 83.9 million in 1997 to 212 million by 2050 [7, 8]. Approximately 2.33 million osteoporotic fractures were estimated to have occurred in 2010, costing $9.45 billion. However, it has been estimated that the annual number and costs of osteoporosis-related fractures will increase to 5.99 million fractures, costing $25.43 billion, by 2050 [9]. The researchers in a previous cross-section survey found that 47.7% of fragility fracture patients aged 80 years and over had osteoporosis, 40.9% of them had osteopenia, while only 11.4% of them had normal bone mass. The risk factors of fragility fracture were found to be falls and lumbar bone mineral density (BMD) reduction [10].

The prevention of fragility fractures has shifted from simple anti-osteoporosis treatment to a combination of treatment and fall prevention action, and the importance of the latter is gaining more attention [4]. However, it is very difficult for clinicians to screen and follow-up with the elderly in the community. People’s awareness of osteoporosis is also poor, and its harm to the human body is not understood, so the treatment rate is low, and many patients are not diagnosed until they have a fracture. This leads to an increase in the incidence of fragility fractures. Therefore, in the present study, the risk factors of new falls and fragility fractures in self-caring elderly patients aged 80 years and over were prospectively analyzed. Initial screening evaluation tools suitable for use in the community were recommended, and high-risk persons were screened ahead of time. The researchers cooperated with hospitals to further analyze the underlying causes and carry out early intervention and follow-up, so as to effectively extend the life and self-care time of the elderly while at the same time reducing the social and economic costs involved [6, 11].

Methods

Subjects

The inclusion criteria were as follows: patients aged ≥80 years and above who were able to take care of themselves. The exclusion criteria were as follows: patients with hyperthyroidism or hypothyroidism, primary hyperparathyroidism or hypothyroidism, Cushing’s syndrome, osteomalacia, malignant tumor, chronic kidney disease (stage 5), cirrhosis, or chronic obstructive pulmonary disease (COPD) (grade 4).

Between January and June 2018, 300 eligible patients from the Outpatients Department of Geriatrics of Beijing Tongren Hospital were enrolled in the study, having given their consent, and each person was monitored for 12 months.

Medical history collection and risk evaluation

The present study adopted a prospective cohort study design. Any new falls and new fragility fractures in these patients during the 12-month follow-up period were recorded. Baseline data were collected either by means of self-reporting or carer-reporting, and through a review of the patient’s medical history and imaging results. During the study, data were collected by the researcher via the outpatient visits of the participants, or via telephone contact. When there was a new fall, and the X-ray showed compressive changes in the thoracolumbar spine, the participants would go to the orthopedics department to obtain confirmation of a fragility fracture.

The patient’s medical history (consultation and review of previous medical records) and physical examination results were collected by specially trained doctors at an osteoporosis and falls clinic. The ability to cope with daily living activities was assessed by the Activity of Daily Living (ADL) scale (Barthel Index), which is scored as follows: 100 points = ADL complete self-care; 75–95 points = mild functional impairment; 50–70 points = moderate functional impairment; 25–45 points = severe functional impairment; 0–20 points = very serious functional impairment. A score of ≥75 was defined as being capable of basic self-care [12]. The fall risk assessment (FRA) scale was used for rating fall risk: low risk 1–2
points, medium risk 3–9 points, and high risk ≥10 points [13]. The height and weight of patients were measured by a specially trained nurse. Muscle strength was measured using the grip strength method, whereby the grip strength of the subjects was measured with a Jamar hand grip (Sammons Preston, USA), and the patients’ hands were tested twice each, the higher value being recorded. A male grip strength of < 30 kg and a female one of < 20 kg was regarded as showing decreased muscle strength [14]. The muscle function was evaluated using the usual gait speed (UGS). Patients were tested by a step speed test over a distance of 6 m, and a walking speed of < 0.8 m/s was defined as showing decreased walking ability. For the timed up & go (TUG) test, the subjects stood up from a seat with an armrest at a normal height (the seat height was approximately 48 cm and the armrest height was approximately 68 cm), walked at their normal walking speed for 3 m, then turned, returned and sat down again, and the time from standing up to sitting down again was recorded [15]. A TUG result of > 12 s was defined as having a high risk of falls [16]. Finally, the chair rising test (CRT) consisted of the subjects standing up and sitting down again five times from a chair of normal height (the height of the seat was approximately 48 cm). The time from first standing up to the 5th time they sat down and touched the chair was recorded. A CRT result of > 10 s or < 5 times was defined as representing a high fall risk [17].

**Determination of the biochemical indexes**

Between 8 and 10 am, 10 ml of elbow vein fasting blood was collected and immediately sent to the laboratory to test the patient’s renal function [blood urea nitrogen (BUN), creatinine (Cr), albumin (ALB)], electrolytes (Ca²⁺ and inorganic phosphorus), intact parathyroid hormone (PTH), total testosterone (T), and estradiol (E2), using a Beckman CX4CE automatic biochemical analyzer. The type I amino-terminal propeptide (P1NP), β-C-terminal telopeptide of type I collagen (β-CTx), osteocalcin (OC), and 25-hydroxyvitamin (25OHD) were detected with a Japanese Roche 60 L immunoluminescent analyzer, using electrochemical luminescence, the kit being produced by Roche Diagnostics (Germany). The serum calcium level was the serum calcium (mmol/L) corrected by albumin = serum calcium (mmol/L) + (0.8–0.02 × albumin [g/L]). The eGFR level was calculated according to the MDRD formula.

**BMD and X-ray scans**

The BMD and T-score of lumbar 1–4, bilateral femoral neck and total hip were measured with a dual-energy X-ray absorptiometry (DXA) produced by GE (USA). The diagnosis was made based on the lowest T-value, according to the World Health Organization (WHO) diagnostic criteria, which are as follows: Normal bone mass T-value≥−1; osteopenia −2.5<T-value<−1; and, osteoporosis T-value ≤−2.5 [5]. Patients with obvious lower back pain or a decrease in height of ≥4 cm had to undergo a non-enhanced lateral X-ray scan of the thoracolumbar spine. During the observation period, if there was a new fall or severe back pain, the thoracolumbar XR was examined, and if there was compression of the vertebral body, the patient was referred to the orthopedic department for further diagnosis of a new or old fracture.

**Statistical analysis**

Data were statistically analyzed using SPSS18.0 software. The test of normality of measurement data was carried out first. Normally distributed measurement data were expressed as mean ± standard deviation, and the measurement data that were normally distributed after the log conversion were expressed as mean (95% confidence interval). The means were compared using two independent sample t-tests. Non-normally distributed data were expressed as the median (interquartile range) and compared using a nonparametric test. Count data were expressed as a percentage and compared using a Chi-square test. The analysis of related factors was carried out using binary logistic regression. P<0.05 was considered statistically significant.

**Results**

**Basic information**

The average age of these patients was 83.92 ± 3.28 years, and 187 patients (62.3%) were male and 113 patients (37.7%) were female. The ratio of M:F=1.65:1 as women were less willing than men to participate in the study. The patients were all residents of Beijing.

During the 12-month observational period, ten of the 300 patients initially selected stopped participating in the study; four patients broke off contact with the investigators and six of them died, the cause of death of three of them being severe pneumonia and that of the remaining patients being lung cancer, sudden cardiac death, and cerebral hemorrhage. In the end, a total of 290 persons were included in the statistical analysis.

A comparison of new falls among populations with different characteristics and the related factors of new falls

In the present study, 87 persons had new falls, the incidence being 30% (87/290). It was found that people that took part in outdoor activities of < 30 min/day, people who were older than 80 years of age, people with diabetes mellitus, people with a walking speed of < 0.8 m/s, and people with a TUG result of > 12 s were more likely to have new falls, and the difference was statistically
significant \( (P<0.05, P<0.01, \text{ Table 1}) \). Compared with patients who did not have any new falls, these patients had a lower ADL (Barthel Index) score, higher FRA score, lower testosterone level, lower grip strength, lower walking speed, lower right femoral neck and total hip BMD, and longer TUG and CRT, the differences being statistically significant \( (P<0.05, P<0.01) \). See Table 2.

An analysis of the related factors revealed that the ADL (Barthel Index) score was negatively correlated with new falls \( (\text{OR}=0.911 \ [0.850–0.976], P=0.008) \), while

### Table 1 The comparison of new falls and fractures in populations with different characteristics

| Item                      | Number of cases n(%) | Number of new falls n(%) | \( p \) | New brittle fractures n(%) | \( p \) |
|---------------------------|-----------------------|--------------------------|-------|---------------------------|-------|
| Gender                    |                       |                          |       |                           |       |
| Male                      | 180 (62.1%)           | 48 (26.7%)               | 0.116 | 12 (6.7%)                 | 0.016 |
| Female                    | 110 (37.9%)           | 39 (35.5%)               |       | 17 (15.5%)                |       |
| Outdoor activities        |                       |                          |       |                           |       |
| < 30 min/d                | 80 (27.6%)            | 32 (40.0%)               | 0.048 | 14 (17.5%)                | 0.031 |
| 30 min-1 h/d              | 64 (22.1%)            | 14 (21.9%)               | 5.78  |                           |       |
| > 1 h/d                   | 146 (50.3%)           | 41 (28.1%)               | 10.68 |                           |       |
| Falls occurring after 80  |                       |                          |       |                           |       |
| Yes                       | 155 (53.4%)           | 56 (36.1%)               | 0.015 | 17 (11.0%)                | 0.556 |
| No                        | 135 (46.6%)           | 31 (23.0%)               |       | 12 (8.9%)                 |       |
| The history of fracture   |                       |                          |       |                           |       |
| Yes                       | 72 (24.8%)            | 27 (37.5%)               | 0.109 | 13 (18.1%)                | 0.009 |
| No                        | 218 (75.2%)           | 60 (27.5%)               |       | 16 (7.3%)                 |       |
| Coronary heart disease    |                       |                          |       |                           |       |
| Yes                       | 133 (45.9%)           | 45 (33.8%)               | 0.190 | 11 (8.3%)                 | 0.366 |
| No                        | 157 (54.1%)           | 42 (26.8%)               |       | 18 (11.5%)                |       |
| Cerebral blood Tube disease|                       |                          |       |                           |       |
| Yes                       | 109 (37.6%)           | 36 (33.0%)               | 0.383 | 12 (11.0%)                | 0.657 |
| No                        | 181 (62.4%)           | 51 (28.2%)               |       | 17 (9.4%)                 |       |
| Diabetes                  |                       |                          |       |                           |       |
| Yes                       | 89 (30.7%)            | 34 (38.2%)               | 0.043 | 10 (11.2%)                | 0.641 |
| No                        | 201 (69.3%)           | 53 (26.4%)               |       | 19 (9.5%)                 |       |
| Chronic kidney disease    |                       |                          |       |                           |       |
| Stage 1                   | 57 (19.7%)            | 21 (36.8%)               | 0.444 | 8 (14.0%)                 | 0.252 |
| Stage 2                   | 160 (55.2%)           | 46 (28.8%)               |       | 17 (10.6%)                |       |
| Stage 3-4                 | 73 (25.2%)            | 20 (27.4%)               |       | 4 (5.5%)                  |       |
| Osteoporosis              |                       |                          |       |                           |       |
| Normal bone mass          | 78 (26.9%)            | 18 (23.1%)               | 0.229 | 4 (5.1%)                  | 0.221 |
| Low bone mass             | 127 (43.8%)           | 39 (30.7%)               |       | 14 (11.0%)                |       |
| Osteoporosis              | 85 (29.3%)            | 30 (35.3%)               |       | 11 (12.9%)                |       |
| Walking speed\(_2\)       |                       |                          |       |                           |       |
| \( \geq 0.8 \text{ m/s} \) | 170 (66.4%)           | 42 (24.7%)               | 0.014 | 9 (5.3%)                  | 0.002 |
| \( < 0.8 \text{ m/s} \)   | 86 (33.6%)            | 34 (39.5%)               |       | 15 (17.4%)                |       |
| TUG                       |                       |                          |       |                           |       |
| \( \leq 12 \text{ s} \)   | 121 (47.3%)           | 25 (20.7%)               | 0.003 | 3 (2.5%)                  | 0.000 |
| \( > 12 \text{ s} \)      | 135 (52.7%)           | 51 (37.8%)               |       | 21 (15.6%)                |       |
| CRT                       |                       |                          |       |                           |       |
| \( \leq 10 \text{ s} \)   | 35 (13.7%)            | 9 (25.7%)                | 0.580 | 2 (5.7%)                  | 0.424 |
| \( > 10 \text{ s} \)      | 221 (86.3%)           | 67 (30.3%)               |       | 22 (10.0%)                |       |
| Treatment plan            |                       |                          |       |                           |       |
| \( \text{Ca}^{2+} / \text{VitD} \) | 46 (15.9%)            | 12 (26.1%)               | 0.220 | 2 (4.3%)                  | 0.318 |
| \( \text{Ca}^{2+} + \text{Active VitD} \) | 123 (42.4%)           | 32 (26.0%)               |       | 15 (12.2%)                |       |
| \( \text{Ca}^{2+} + \text{Active VitD+anti-osteoporosis drugs} \) | 121 (41.7%)          | 43 (35.5%)               |       | 12 (9.9%)                 |       |
| New falls                 |                       |                          |       |                           |       |
| Yes                       | 87 (30.0%)            | 24 (27.6%)               |       | 0.000                     |       |
| No                        | 203 (70.0%)           | 5 (2.5%)                 |       |                           |       |
| New brittle fractures     |                       |                          |       |                           |       |
| Yes                       | 29 (10.0%)            | 24 (82.8%)               |       | 0.000                     |       |
| No                        | 261 (90.0%)           | 63 (24.1%)               |       |                           |       |
| Total                     | 290                   | 87                       |       |                           |       |

TUG timed up & go test, CRT chair rising test, History of falls: falls occurring after 80 years old
the TUG results of > 12 s were positively correlated with new falls (OR=1.980 [1.109–3.532], P=0.021). See Table 3.

A comparison of new fragility fractures among populations with different characteristics and related factors of new fragility fractures

In the present study, 33 fragility fractures occurred in 29 patients (10.0%), the incidence being 10.0% (29/290). The fracture sites were the thoracolumbar vertebrae (42.4%, 14/33), hip (30.3%, 10/33), distal forearm (12.1%, 4/33), and other body parts (ribs, clavicles, elbows, and skull) (15.2%, 5/33).

Among these patients, the female patients with outdoor activities of < 30 min/day, a history of fragility fractures, a walking speed of < 0.8 m/s, a TUG result of > 12 s, and new falls were more likely to have new fragility fractures, the difference being statistically significant (P< 0.05, P< 0.01). See Table 1. Compared with patients without new fragility fractures, these patients had a higher FRA score, lower grip strength, lower walking speed, lower right femoral neck and total hip BMD, longer TUG and CRT, and the differences were statistically significant (P< 0.05, P< 0.01). See Table 4.

An analysis of the related factors revealed that new falls were significantly positively correlated with new fragility fractures (OR=11.885 [3.914–36.087], P=0.000). The BMD of lumbar vertebrae and walking speed were significantly negatively correlated with new fragility fractures, (OR=0.092 [0.014–0.596], P=0.012, OR=0.011 [0.001–0.124], P=0.000, respectively). See Table 5.

Table 2. The comparison of the data in patients with new falls and without falls

| Items                  | With new falls(n=87) | Without new fall experiences(n=203) | P   |
|------------------------|----------------------|------------------------------------|-----|
| Age (years)            | 84.4±3.5             | 83.6±3.1                           | 0.058|
| BMI (kg/m²)            | 23.2±3.2             | 23.7±3.0                           | 0.247|
| ADL (score)            | 95 (95, 100)         | 100 (95, 100)                      | 0.001|
| FRA (score)            | 10 (10, 12)          | 10 (8, 11)                         | 0.000|
| Ca²⁺ (mmol/L)          | 2.31±0.10            | 2.33±0.09                          | 0.122|
| Inorganic phosphorus (mmol/L) | 1.11±0.16         | 1.11±0.16                          | 0.773|
| PTH (pg/mL)            | 44.21 (39.79–48.85)  | 44.31 (40.94–47.65)                | 0.411|
| E₂ (pg/mL)             | 30.36±19.19          | 31.86±19.08                        | 0.547|
| T (ng/mL)              | 1.93 (0.9, 3.01)     | 2.57 (0.33, 3.77)                  | 0.022|
| 25OHD (ng/mL)          | 20.32±9.26           | 21.76±11.85                        | 0.313|
| eGFR (ml/min)          | 75.98±22.32          | 72.70±19.36                        | 0.209|
| OC (ng/mL)             | 12.47 (11.36~13.90)  | 13.14 (12.35~13.90)                | 0.251|
| P1NP (ng/mL)           | 31.99 (29.54~34.78)  | 31.48 (29.29~33.87)                | 0.410|
| β-CTX (ng/mL)          | 0.18 (0.13, 0.29)    | 0.21 (0.14,0.30)                   | 0.216|
| L₁₋₄BMD (g/cm²)        | 1.18±0.31            | 1.16±0.25                          | 0.611|
| LnBMD (g/cm²)          | 0.76±0.15            | 0.79±0.16                          | 0.167|
| RnBMD (g/cm²)          | 0.75±0.14            | 0.80±0.16                          | 0.015|
| L₁BMD (g/cm²)          | 0.84±0.16            | 0.86±0.17                          | 0.308|
| R₁BMD (g/cm²)          | 0.82±0.16            | 0.86±0.17                          | 0.032|
| Grip (kg)              | 24.51±6.93           | 27.18±8.95                         | 0.010|
| Walking speed (m/s)    | 0.84±0.24            | 0.96±0.25                          | 0.001|
| TUG (s)                | 15.43 (13.78~17.48)  | 13.16 (12.48~13.94)                | 0.009|
| CRT (s)                | 16.32 (14.90~17.88)  | 14.65 (13.88~15.46)                | 0.027|

BMI Body Mass Index, ADL Activity of Daily Living scale, FRA The fall risk assessment, PTH parathyroid hormone, E₂ estradiol, T Total testosterone, 25(OH)D 25-hydroxyvitamin D, eGFR glomerular filtration rate, OC osteocalcin, P1NP type I amino-terminal propeptide, β-CTx β-C-terminal telopeptide of type I collagen, L₁₋₄BMD bone mineral density of lumbar, LnBMD bone mineral density of left femoral neck, RnBMD bone mineral density of right femoral neck, L₁BMD bone mineral density of left total hip, R₁BMD bone mineral density of right total hip, TUG timed up & go, CRT chair rising test

Table 3. The related factors of new falls

| Factor     | B    | S.E. | Wald  | P     | OR (95%CI)       |
|------------|------|------|-------|-------|-----------------|
| ADL        | −0.093 | 0.035 | 6.933  | 0.008 | 0.911 (0.850–0.976) |
| TUG>12 s   | 0.683 | 0.295 | 5.342  | 0.021 | 1.980 (1.109–3.532) |
| Constant   | 7.143 | 3.567 | 4.010  | 0.045 | 1264.667 |

ADL Activity of Daily Living, TUG TUG>12 s
Discussion

The elderly population has a high risk of falls and needs to receive assessment of fall-related risk factors and intervention when required [18]. The present study involved people aged 80 years and over who could care for themselves in the community. Their daily activities, underlying diseases, biochemical indexes, 25(OH)D, sex hormones, parathyroid hormone levels (PTH), bone turnover markers, BMD, muscle strength, muscle function, balance function, and use of anti-osteoporosis drugs were analyzed and prospectively observed for 12 months.

This study revealed that compared with patients who did not have falls, patients with new falls had a higher FRA score, lower ADL (Barthel Index) score, lower testosterone, lower BMD of the femoral neck and total hip, lower grip strength, lower walking speed, and longer TUG and CRT. The logistic regression analysis further revealed that the low ADL (Barthel index) score and TUG of > 12 s were the risk factors of new falls in the elderly with a basic self-care ability. The TUG test is a method developed by the McGill University of Canada to test functional mobility [19]. In clinical practice, it is believed that this method can be used to simply and reliably evaluate patients’ ability to balance, their coordination function, joint range of motion, and reflex control, and, thus, it is used to predict fall risk [20, 21]. It is also an independent predictor of non-vertebral and hip fractures [20]. The American and British Geriatric Societies [22] and the National Institute of Clinical Evidence (NICE) guidelines [23] recommend the TUG as a clinically useful tool for assessing gait, strength, and balance in the risk of falls in elderly patients. A prospective cohort study in the UK revealed that TUG was significantly and independently correlated with the future falls of people aged 65 years and over [24]. The present study also revealed that TUG is suitable for the prediction of new falls in the elderly aged ≥80 years old in the community. A TUG result of < 10 s indicates a person is

| Table 4 | The comparison of the data in patients with new fractures and without fractures |
|---------|--------------------------------------------------------------------------------|
| Items   | With new brittle fractures(n=29) | Without new brittle fractures(n=261) | P     |
| Age (years) | 84.9±2.9 | 83.8±3.3 | 0.078 |
| BMI (kg/m²) | 22.9±3.5 | 23.6±3.0 | 0.242 |
| ADL (score) | 100 (90, 100) | 100 (95, 100) | 0.288 |
| FRA (score) | 11 (10, 14) | 10 (8, 11) | 0.003 |
| Ca²⁺ | 2.30±0.10 | 2.33±0.09 | 0.157 |
| Inorganic phosphorus (mmol/L) | 1.11±0.15 | 1.11±0.16 | 0.916 |
| PTH (pg/mL) | 42.35 (36.40–48.77) | 44.48 (41.46–47.34) | 0.721 |
| E₂ (pg/mL) | 30.85±20.53 | 31.47±18.98 | 0.874 |
| T (ng/mL) | 0.59 (0.23, 3.13) | 2.33 (0.33, 3.58) | 0.183 |
| 25OHD (ng/mL) | 22.70±7.57 | 21.18±11.47 | 0.485 |
| eGFR (mL/min) | 79.24±27.03 | 73.07±19.39 | 0.121 |
| OC (ng/mL) | 11.71 (9.96–13.58) | 13.07 (12.40–13.81) | 0.229 |
| P1NP (ng/mL) | 30.64 (26.35–34.90) | 31.73 (29.84–33.70) | 0.905 |
| β-CTX (ng/mL) | 0.19 (0.13, 0.25) | 0.20 (0.14, 0.29) | 0.542 |
| L₁−₄BMD (g/cm²) | 1.04±0.23 | 1.18±0.27 | 0.009 |
| L₁BMD (g/cm²) | 0.72±0.16 | 0.79±0.16 | 0.030 |
| R₁BMD (g/cm²) | 0.72±0.12 | 0.79±0.16 | 0.015 |
| L₂BMD (g/cm²) | 0.80±0.14 | 0.86±0.17 | 0.089 |
| R₂BMD (g/cm²) | 0.78±0.14 | 0.86±0.17 | 0.013 |
| Grip (kg) | 21.14±6.78 | 26.95±8.45 | 0.001 |
| Walking speed (m/s) | 0.70±0.19 | 0.95±0.25 | 0.000 |
| TUG (s) | 17.61 (14.96–20.80) | 13.45 (12.74–14.28) | 0.000 |
| CRT (s) | 18.25 (15.45–21.31) | 14.83 (14.12–15.59) | 0.005 |

| Table 5 | The related factors of new fractures |
|---------|-----------------------------------|
| Factor  | B   | S.E. | Wald  | P     | OR (95%CI) |
| New falls | 2.475 | 0.567 | 19.080 | 0.000 | 11.885 (3.914–36.087) |
| L₁−₄BMD | −2.385 | 0.953 | 6.261 | 0.012 | 0.092 (0.014–0.596) |
| Walking speed | −4.521 | 1.241 | 13.264 | 0.000 | 0.011 (0.001–0.124) |
| Constant | 2.731 | 1.453 | 3.535 | 0.060 | 15.345 |
independently mobile, a TUG result of $<20\,\text{s}$ means a person is mostly capable of independent activity, a TUG result of $20–29\,\text{s}$ indicates instability, and a TUG result of $>30\,\text{s}$ suggests some dyskinesia [16]. Studies concluded that a TUG result of $\geq13.5\,\text{s}$ could be used as an evaluation index of fall risk. However, a TUG result of $13.5\,\text{s}$ has not been widely proven to be the most appropriate critical value. This study revealed that a TUG result of $>12\,\text{s}$ increased the risk of falls by 98% in the elderly population enrolled in this study. Therefore, although TUG can be used to predict new falls in the elderly in the community, more research is needed to determine the critical value for future assessments.

The daily activity ability of elderly people is correlated with cognitive and psychological status. Fauth et al. showed that even after controlling for baseline cognitive status, ADL dysfunction was still an important predictor of dementia risk, and to a lesser extent, it was also affected by psychological and environmental factors. In this study, the median (quarterback interval) of ADL scores of the included samples is 100 (95, 100), which can initially exclude dementia [25], but not Mild Cognitive Impairment (MCI) [26]. The inclusion of tools such as the MINI-mental Status Exam, Home Fall HiHA (HIHA) and other kinds of psychological assessment will ensure the comprehensive assessment of fall risks for elderly people in the future.

Intrinsic capacity is defined as the resilience that an individual has to overcome a variety of environmental, physical and psychological factors. When a person declines at a more rapid rate than the age-related decline in intrinsic capacity, they are said to be exhibiting frailty [27]. Physical frailty was operationalized by Fried et al. [28], who defined it as the presence of three or more of the following: fatigue, weight loss, weakness, slow walking gait and limited physical activity. Since frail persons are at a greater risk of falls, the assessment of frailty should also be added in future studies.

For the elderly, fragility fractures in themselves are not fatal but the underlying diseases and multiple system complications of the elderly are often the main causes of the high fatality rate. The 1-year mortality rate of elderly patients with hip fractures is $12–37\%$, and approximately half of the patients did not recover their independent living ability [18]. BMD alone has high specificity but low sensitivity in evaluating the risk of fractures. Therefore, BMD alone is not recommended for population screening [29]. Moreover, FRAX tools do not include fall factors in the calculation, and this may lead to an underestimation of the fracture risk of this population [30]. In the present study, the incidence of fragility fractures within 12 months was 10.0% and the main three fracture sites were the thoracolumbar spine, hip, and distal forearm. Female patients with an outdoor activity of $<30\,\text{min/day}$, a previous fragility fracture history, a high FRA score, new falls, low BMD, low muscle strength, low muscle function, and low balance function were more likely to have new fragility fractures. Previous studies have also revealed that female menopause was the most common cause of osteoporosis. Within 3–5 years of menopause, due to the lack of estrogen in the body, the bone mass of females will be rapidly lost, and this can cause osteoporosis or even fragility fractures [30]. Other diseases with a high incidence in the elderly, such as diabetes, rheumatic immune diseases, and liver and kidney dysfunction, will also affect bone metabolism, leading to a decrease in the total amount and quality of bones, and an increase in the likelihood of osteoporosis and fragility fractures [31]. The logistic regression analysis further revealed that new falls, low BMD of the lumbar vertebrae, and low walking speed were the significant risk factors of new fragility fractures. A previous study also revealed that the decreasing BMD of the lumbar vertebrae after 80 years of age was correlated to vascular calcification and joint degeneration in the lumbar vertebrae [32].

The strength of this study is that by analyzing the data, we have shown that evaluation tools that are inexpensive and simple to use, such as walking speed, TUG, ADL, and FRA, can be used to screen for falls and fragility fractures in the elderly population. However, limitations also exist, because as a common senile syndrome, falls have multiple potential risk factors. This study explored falls in the older population and preliminary screening tools for brittle fracture risk and focused on the functional assessment of physical activity, but it did not consider cognitive, psychological, social, or environmental factors, or medication. Further research will focus on screening out the physical activity of functional relation between loss and fall over and over again the crowd, multi-factor comprehensive assessment and mechanism research.

**Conclusion**

This study has demonstrated that inexpensive and straightforward evaluation tools can be used to screen for high fall risk and fragility fractures in the elderly population. Subsequently, those at risk can be recommended to the hospital for further examination, individual intervention programs can be developed, and follow-up can be carried out in the community. The researchers hope to use these assessment methods to effectively reduce the incidence of falls and fragility fractures, and shorten the disability period of the elderly after experiencing a fall and fragility fracture, thereby improving their health and quality of life, and reducing the associated pressure on the family and the social care system.
Abbreviations
BMD: Bone mineral density; COPD: Chronic obstructive pulmonary disease; ADL: Activity of Daily Living; FRA: Fall risk assessment; UGS: Usual gait speed; TUG: timed up & go; CRT: Chair rising test; BUN: Blood urea nitrogen; Cr: Creatinine; ALB: Albumin; PTH: Parathyroid hormone; T: Total testosterone; E2: Estradiol; P1NP: Type I amino-terminal propeptide; β-CtX: β-C-terminal telopeptide of type I collagen; OC: Osteocalcin; 25OHD: 25-Hydroxyvitamin; DXA: Dual-energy X-ray absorptiometry; WHO: World Health Organization

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Authors’ contributions
ZJ and LB conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. QMZ, and LJP designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and revised the manuscript. LB coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Availability of data and materials
Not applicable.

Ethics approval and consent to participate
This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Beijing Tongren Hospital, Capital Medical University. A written informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
All authors have contributed significantly to the manuscript and declare that the work is original and has not been submitted or published elsewhere. All authors have contributed significantly to the manuscript and declare that the work is original and has not been submitted or published elsewhere. All authors have contributed significantly to the manuscript and declare that the work is original and has not been submitted or published elsewhere.

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References
1. Chini LT, Pereira DS, Nunes AA. Validation of the Fall Risk Tracking Tool (FRRiSque) in elderly community dwellers. Cien Saude Colet. 2019;24(8):2845–58.
2. Park BM, Ryu HS, Kwon KE, Lee CY. Development and Effect of a Fall Prevention Program Based on the King’s Goal Attainment Theory for Fall High-Risk Elderly Patients in Long-Term Care Hospital. J Korean Acad Nurs. 2019;49(2):203–14.
3. Barrett-Connor E, Weiss TW, McHoney CA, Miller PD, Sires S. Predictors of falls among postmenopausal womenresults from the National Osteoporosis Risk Assessment (NORA). Osteoporos Int. 2009;20(5):715–22.
4. Järvinen TL, Seivalien H, Khan KM, Heinonen A, Kannus P. Shifting the focus in fracture prevention from osteoporosis to falls. BMJ. 2008;336(7636):124–6.
5. Kanis JA, Oden A, Johnell O, Jonsson B, de Laet C, Dawson A. The burden of osteoporotic fractures: a method for setting intervention thresholds. Osteoporos Int. 2001;12(5):417–27.
6. Hilligsmann M, Kanis JA, Compston J, Cooper C, Flannion B, Bergmann P, et al. Health technology assessment in osteoporosis. Calcif Tissue Int. 2013;93(1):1–14.
7. National economic and social development statistical bulletin 2015 [webpage on the Internet]. National Bureau of Statistics of the People’s Republic of China. Available from http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm. Accessed 9 Mar 2019.
8. Lin X, Xiong D, Peng YQ, Sheng ZF, Wu XY, Wu XP, et al. Epidemiology and management of osteoporosis in the People’s Republic of China: current perspectives. Clin Interv Aging. 2015;10:1017–33.
9. S L, Winzenberg TM, Jiang Q, Chen M, Palmer AJ. Projection of osteoporosis-related fractures and costs in China. 2010–2050. Osteoporos Int. 2015;26(7):1920–37.
10. Zhou J, Qin MZ, Liu Q, Liu JP. Investigation and analysis of osteoporosis, falls, and fragility fractures in elderly people in the Beijing area: a study on the bone health status of elderly people ≥ 80 years old with life self-care. Arch Osteoporos. 2011;6(1):118.
11. Li F, Eckstrom E, Harmer P, Fitzgerald K, Voit J, Cameron KA. Exercise and fall prevention: narrowing the research-to-practice gap and enhancing integration of clinical and community practice. J Am Geriatr Soc. 2016;64(2):425–31.
12. Mackaay RL, Ali M, Taylor-Rowan M, Rodgers H, Lees KR, Quinn TJ, Collaborators VISTA. Use of a 3-Item Short-Form Version of the Barthel Index for Use in Stroke: Systematic Review and External Validation. Stroke. 2017;48(3):618–23.
13. Nunnan S, Brown Wilson C, Henwood T, Parker D. Fall risk assessment tools for use among older adults in long-term care settings: A systematic review of the literature. Australas J Ageing. 2018;37(1):23–33.
14. Bohannon RW. Muscle strength: clinical and prognostic value of hand-grip dynamometry. Curr Opin Clin Nutr Metab Care. 2015;18(3):465–70.
15. Peel NM, Kuyk SS, Klein K. Gait speed as a measure in geriatric assessment in clinical settings: a systematic review. J Gerontol A Biol Sci Med Sci. 2013;68(1):39–46.
16. Chow RB, Lee A, Kane BG, Jacoby JL, Barraco RD, Dusza SW, et al. Effectiveness of the “Timed Up and Go” (TUG) and the Chair test as screening tools for geriatric fall risk assessment in the ED. Am J Emerg Med. 2019;37(3):457–69.
17. Rupp T, Butscheidt S, Jähn K, Simon MJ, Musawwy H, Oheim R, et al. Low physical performance determined by chair rising test muscle mechanography is associated with prevalent fragility fractures. Arch Osteoporos. 2018 Jul 2;13(1):71.
18. US Preventive Service Task Force, Grossman DC, Cury SJ, Owens DK, Barry MJ, Caughey AB, Davidson KW, Doubeni CA, Epling JW Jr, Kemper AR, Krist AH, et al. Interventions to Prevent Falls in Community-Dwelling Older Adults: US Preventive Service Task Force Recommendation Statement. JAMA. 2018;319(1696–704).
19. Podsiadlo D, Richardson S. The timed ‘Up & Go’: a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991 Feb;39(2):142–8.
20. Zhu K, Devine A, Lewis JR, Dhaliwal SS, Prince RL. ‘Time up and go’ test and bone mineral density measurement for fracture prediction. Arch Intern Med. 2011;171(18):1655–61.
21. Nightingale CJ, Mitchell SN, Butterfield A. Validation of the Timed Up and Go Test for Assessing Balance Variables in Adults Aged 65 and Older. J Aging Phys Act. 2019;27(2):230–3.
22. Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society. Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. J Am Geriatr Soc. 2011;59:148–57.
23. NICE. The assessment and prevention of falls in older people. 2013. http://www.nice.org.uk/CG161.
24. Kojima G, Masud T, Kendrick D, Morris R, Gawler S, Treml J, Iliffe S. Does the ‘Timed Up and Go’ Test Predict Fracture Risk in Older People? Prospective cohort study nested within a randomized controlled trial. BMC Geriatr. 2015;15(1):38.
25. Fauth EB, Schwartz S, Tschanz JT, Østbye T, Corcoran C, Norton MC. Baseline disability in activities of daily living predicts dementia risk even after controlling for baseline global cognitive ability and depressive symptoms. Int J Geriatr Psychiatry. 2013;28(6):597–606.
26. Greenaway MC, Duncan NL, Hanna S, Smith GE. Predicting functional ability in mild cognitive impairment with the dementia rating scale-2. Int Psychogeriatr. 2012;24(6):987–93.
27. Morley JE. Physical frailty: a biological marker of aging? J Nutr Health Aging. 2020;24(10):1040–1.
28. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Cardiovascular Health Study Collaborative Research Group. Frailty in older adults: Evidence for a phenotype. J Gerontol A Biol Sci Med Sci. 2001;56(3):M146–56.
29. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. JAMA. 2009;302:1573–9.
30. LeBlanc ES, Hillier TA, Pedula KL, Rizzo JH, Cawthon PM, Fink HA, et al. Hip fracture and increased short-term but not long-term mortality in healthy older women. Arch Intern Med. 2011;171:1831–7.
31. National Institute for Health and Care Excellence. NICE Clinical Guideline 146. In: Osteoporosis: assessing the risk of fragility fracture; 2012.
32. Masud T, Binkley N, Boonen S, Hannan MT, FRAX® Position Development Conference Members. FRAX® Position Development Conference Members Official Positions for FRAX® clinical regarding falls and frailty: can falls and frailty be used in FRAX® From joint official positions development conference of the International Society for Clinical Densitometry and International Osteoporosis Foundation on FRAX®, J Clin Densitom. 2011;14(3):194–204.

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