Relationships between falls, vertebral fractures, increased kyphosis and a flexed posture in elderly: a prospective cohort study

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Submitted
Abstract

Introduction: Vertebral fractures, thoracic kyphosis and flexed posture are associated with reported falls in cohort studies with elderly, but not yet confirmed as a risk factor in a prospective study. The purpose of the present study was to investigate whether elderly patients with vertebral fractures, hyperkyphosis or flexed posture experience more fall incidents than patients without these clinical entities.

Methods: Patients were recruited in a geriatric hospital outpatient clinic and included if they could walk independently for 3 minutes without an asymmetric walking pattern. Lateral radiographs of the spine were taken to evaluate vertebral fractures with the semi-quantitative method of Genant, and to assess the degree of thoracic kyphosis using the Cobb angle: hyperkyphosis was defined as Cobb angle ≥50°. A flexed posture was measured by the occiput-to-wall distance. Self-reported falls were prospectively registered by monthly phone contact for the duration of 12 months.

Results: Fifty-one patients were included; mean age was 79 years (SD=4.8). Hyperkyphosis was a strong independent risk factor for falling with an OR of 6.18 (95% CI: 1.17-32.74). Prevalent vertebral fractures had a trend towards significance (p=0.06). Flexed posture was not significantly associated with prospective falling.

Conclusion: Elderly patients with hyperkyphosis (Cobb angle ≥50°) are more likely to fall within the next year. We recommend implementing hyperkyphosis in fall-risk assessments. Because vertebral fractures can contribute to hyperkyphosis and are usually the result of osteoporosis, falls in these patients raises the risk of a new fracture. The finding of vertebral fractures and particularly hyperkyphosis should alert physicians to start anti-osteoporotic therapy.
Consequences of vertebral fractures on posture, postural control and falls

Introduction
Among elderly persons, fall incidents occur frequently: at least 30-40% of the elderly fall annually [1]. Falls in the older population are generally caused by a combination of risk factors, such as balance disorders, postural instability, poor vision, polypharmacy and environmental factors, and can lead to serious injuries such as fractures [2]. When fractures result of a fall, diminished bone quality due to osteoporosis may contribute to the fracture [3]. However, typical osteoporotic fractures of the vertebrae are commonly not the result of a fall incident, they usually occur during normal daily activities, such as climbing stairs, lifting groceries, or bending forward [4]. The prevalence of vertebral fractures increases with age, and is up to 50% among geriatric patients [5]. Vertebral fractures have a high morbidity, like pain, postural changes, restrictive respiratory disease, poor physical condition and loss of quality of life [6], and are independently associated with increased mortality [7,8]. Very recently, it was shown that the finding of a prevalent vertebral fracture on a Chest X ray was associated with a 3 fold increased risk of a future fracture [9]. Over time, thoracic vertebral fractures can increase the kyphotic curvature of the thoracic spine [10], and may therefore cause a flexed posture [11]. A flexed posture is characterized by an increased thoracic kyphosis, protrusion of the head, and in more severe cases also hip and knee flexion. A flexed posture is the more extreme expression of an increased kyphosis, when the compensatory mechanisms to correct the kyphosis fail [11].

In a systematic review, we recently showed that vertebral fractures, increased thoracic kyphosis and a flexed posture are associated with an impaired postural control [12]. Since impairments in balance and gait are the primary cause of falling [13], it is hypothesized that patients with an increased thoracic kyphosis and/or flexed posture may have an increased risk of falling, and a higher risk of further fractures. Fall risk related to vertebral fractures or kyphosis has been investigated retrospectively in previous studies [14-17]. However, to our knowledge fall incidence has not yet been prospectively investigated in relation to vertebral fractures, hyperkyphosis and flexed posture. Therefore, we designed the present study to investigate whether patients with vertebral fractures, hyperkyphosis or flexed posture fall more often than patients without these entities.

Methods
Patient characteristics
Patients were recruited from the population of elderly patients who visited the geriatric outpatient clinic of the Slotervaart Hospital in Amsterdam between October 2010 and April 2012. They were referred for various reasons, including memory complaints, mobility problems, or reducing polypharmacy. Patients were included for the present study if they were 70 years or older; could walk safely for 3 minutes without using any assistive device (e.g. walking stick or wheeler); and were able to understand and speak Dutch or English. Patients were excluded if they had any mobility problems due to (lateral) neurological or orthopedic disorders with function limitations of one or both legs; or did not understand
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the instructions of the researcher due to severe cognitive impairments. The data from the present cohort were also used in a study examining the effects of a flexed posture on postural control during walking [18]. Each patient had a comprehensive geriatric assessment [19] being standard procedure at the geriatric outpatient clinic. Depending on the conclusions of the geriatrician, work up treatment was started. If the patient was referred to this clinic for falling, or reported falls in the last year, the national guidelines for preventing falls in the future were followed. The present study was approved by the Medical Ethical Committee of the Slotervaart Hospital and Reade. All patients (or their legal substitution makers) gave their informed consent.

Measurements

Gender, age, Body Mass Index, number of prescriptions, any hip replacements in history, and reported falls in the last year were registered. The Charlson Comorbidity Index was assessed to score the presence of comorbid diseases [20]. Patients were cognitively assessed using the Mini Mental State Examination (MMSE) [21]. The criteria of Fried and colleagues were used to determine the presence of frailty in the population [22]. Patients were considered frail or intermediate frail when respectively ≥3 or 1-2 of Fried’s criteria were present: unintentional weight loss (5 kg in the past year), self-reported exhaustion, weakness (grip strength), slow walking speed (less than 0.76 m/s), and low physical activity (<383 kilocalories spent per week for males, and <270 kcal for women, or more than 4 h/day sitting in a chair without walking a longer distance once per month or biking or jogging). Functional mobility was assessed by the Timed Up and Go test [23]. The fall-risk-assessment of Pluijm was assessed [24]. Seven or more points on this scale was considered as increased fall risk. Walking speed (m/s) was measured during a gait assessment as described in [18].

The presence of vertebral fractures was judged on lateral X-rays of the thoracic and lumbar vertebral column. Vertebral fractures were scored by the semi-quantitative technique of Genant [25]. The method of Genant scores the following characteristics of vertebral fractures: (a) the type of the deformation: biconcave deformity (middle of the vertebrae), wedge deformity (anterior) or crush deformity (posterior); and (b) the category of severity: grade I (20-25% height loss), grade II (≥25-40%) or grade III (>40%). All radiographs were scored by two observers (MG, HJ), their conclusions were compared, and if there was a difference, a final conclusion was reached by discussion.

The kyphosis of the thoracic vertebral column was determined by the Cobb angle. This is the angle formed between a line drawn parallel to the superior endplate of the second, and a line parallel to the inferior endplate of the twelfth thoracic vertebra. In the present study, hyperkyphosis was defined as a Cobb angle of ≥50° [26]. The two observers measured the Cobb angle twice, and the mean value of the measurements was used to construct a more reliable outcome. Patients with a Cobb angle <50° were considered as normal.
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The severity of flexed posture was evaluated by measuring the occiput-to-wall distance (OWD), see figure 1. While subjects stand with their head in a natural position, their heels and back touching the wall and their knees as extended as possible, the distance between their occiput and the wall was measured [11]. A flexed posture was defined as an OWD >5.0cm.

Fall incidents were prospectively registered for six months using a falls-and-fracture calendar. A fall was defined as ‘an unexpected event where a person comes to rest on the ground from an upper level or the same level’ [27]. During this follow-up period, patients (or their caregivers) were contacted by phone every month to report fall incidents and/or injuries. When patients had a MMSE score below 24 points, caregivers who lived with the patient were asked to fill in the falls-and-fracture calendar. Since very few fall incidents were reported in the six-month follow-up period, we extended the falls-and-fracture calendar with another six months. We asked every participant for extension of the study by phone, for his or her consent. Main outcome of the study was the first fall during follow-up.

Figure 1: Various postures among geriatric patients

Statistical analysis
PASW Statistics version 18.0 was used for statistical analyses. For all patient characteristics, mean values with standard deviation or median values with range were calculated. The relationship between vertebral fractures, hyperkyphosis and flexed posture with falls was estimated using the Chi-square test. Then, to test which variables were independently associated with falling, first univariate binary logistic analyses were
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performed, and secondly multivariate binary logistic regression analyses were computed. Odds Ratio’s (OR) with 95% Confidence Intervals (CI) were calculated. For the multivariate regression analyses two different models were tested. In the first model (A) all continuous or interval variables (Cobb angle, OWD-distance, frailty score and vertebral fractures score) with a p-value of <0.10 in the univariate analyses were included. The second model (B) included only binary scored variables testing our hypothesis: the presence of vertebral fractures, hyperkyphosis (Cobb angle ≥50°), flexed posture (OWD ≥5cm), and increased fall-risk (Pluijm fall-risk assessment ≥7 points). Both models A and B were not adjusted for age because the patients who felt during follow-up were not older than those who did not fall. We adjusted for gender alone. A backward selection procedure was applied; a forward analysis selected the same variables. The level of significance was set on p<0.05.

Results
During the inclusion period, 139 older patients visited the geriatric outpatient clinic that met the inclusion criteria, whereof 60 persons were willing to participate in the present study. In 9 cases, the falls-and-fracture calendar was not completed, due to lost to follow-up within the first month. Finally, 51 patients were included in the present study. The mean age of the included patients was 79 years, and 77% were female. Body mass index was mean 27.4 kg/m², and the Charlson Comorbidity Index showed that patients had mean 1.4 chronic diseases or conditions (see Table 1 for patients characteristics).

Table 1: Patient characteristics, n = 51

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Age in years, mean (SD)</td>
<td>79.3 (4.8)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>39 (77%)</td>
</tr>
<tr>
<td>BMI in kg/m², mean (SD)</td>
<td>27.4 (4.0)</td>
</tr>
<tr>
<td>Charlon Comorbidity Index score, mean (SD)</td>
<td>1.4 (1.3)</td>
</tr>
<tr>
<td>Number of prescriptions, mean (SD)</td>
<td>5.8 (3.9)</td>
</tr>
<tr>
<td>MMSE score, median (range)</td>
<td>24 (13-30)</td>
</tr>
<tr>
<td>Hip replacement in history, n (%)</td>
<td>7 (14%)</td>
</tr>
<tr>
<td>Walking speed in m/s, mean (SD)</td>
<td>0.86 (0.25)</td>
</tr>
<tr>
<td>Timed up and go test in s, median (range)</td>
<td>13 (6-38)</td>
</tr>
<tr>
<td>Pluijm-risk assessment score, median (range)</td>
<td>11 (22%)</td>
</tr>
<tr>
<td>Vertebral fractures, n (%)</td>
<td>20 (39%)</td>
</tr>
<tr>
<td>Thoracic kyphosis, Cobb angle in degrees, mean (SD)</td>
<td>51.2 (14.5)</td>
</tr>
<tr>
<td>Occiput-to-wall distance in cm, median (range)</td>
<td>4.0 (0-16)</td>
</tr>
</tbody>
</table>

Falls during follow-up:
| No falls, n (%) | 38 (74%) |
| 1 fall, n (%)   | 5 (10%)  |
| ≥ 2 falls during follow-up (range 2-9), n (%) | 8 (16%) |

Mean use of prescriptions was 5.8 per patient. Seven patients (14%) had a hip replacement in history. Seventeen patients (33%) reported at least 2 falls in the year previous to the baseline measurements. Seven patients (14%) were considered frail according to the Fried criteria. Mean walking speed was 0.86 m/s; the timed up and go test was performed in median 13 seconds (range 6-38). According to the Pluijm fall-risk-
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11 (22%) patients had an increased fall risk. Vertebral fractures were diagnosed in 20 cases (39%), whereof 9 patients were diagnosed with moderate or severe vertebral fractures (grade 2 or 3).

The mean follow-up was 10.6 months. Thirty-eight patients (75%) had a follow-up of twelve months with phone contact every month; the other 13 patients had a mean follow-up of 6.2 months. Since patients were asked after 6 months of follow-up whether they wanted to participate for another 6 months, 8 patients refused further follow-up. Other reasons lost to follow-up were: moving to a nursing home (n=3); and being tired of registering high fall incidence (n=2). Thirteen patients (25%) had at least one fall during follow-up; whereof 8 patients were identified as recurrent faller (≥2 falls). Four patients had serious injury after the fall and had to visit a doctor, of whom one had a new non-vertebral fracture.

Relation between vertebral fractures, hyperkyphosis and flexed posture

Figure 2 shows the distribution of vertebral fractures, hyperkyphosis, and flexed posture among the 51 included patients. Among 12 (24%) patients none of the three clinical entities were present. Nine patients were diagnosed with all three entities. The others (30 patients) had one, or a combination of the clinical entities. Vertebral fractures were present in 20 patients (39%).

Figure 2: Illustration of the distribution of patients in the study according to vertebral fractures, hyperkyphosis and flexed posture in relation to falls

The large white rectangle represents all patients in the study (n = 51), whereof in the upper rectangle patients with vertebral fractures (n = 20; 39%); in the bottom left rectangle patients with a hyperkyphosis (n = 28; 55%); and in the bottom right rectangle patients with a flexed posture (n = 22; 44%). Patients with combinations of these clinical entities are represented by the overlapping areas of the other rectangles, with n noted in each box. Twelve patients (24%) had none of the clinical entities present (white rectangle). *9 patients had all clinical entities. **Oval represents all fallers (n = 13); all fallers had at least one of the three clinical entities present. In seven fallers all clinical entities were present.
Hyperkyphosis, defined as a Cobb angle of ≥50°, was seen in 28 (55%) patients. Flexed posture, as classified by an OWD >5 cm, was present in 22 patients. Of the 20 patients with vertebral fractures, 13 (65%) had also hyperkyphosis ($\chi^2 = 1.36; \ p=0.24$). Hyperkyphosis was significantly related to the presence of a flexed posture ($\chi^2 =11.32; \ p<0.01$). The relation between flexed posture and vertebral fractures was not significant ($\chi^2=0.47; \ p=0.83$).

Relation of vertebral fractures, hyperkyphosis and flexed posture with prospective falls

All 13 fallers in this cohort (see also Figure 2) were diagnosed with vertebral fractures, hyperkyphosis and/or flexed posture. Nine fallers had two or three of these clinical entities present. Eight of the 13 fallers had one or more prevalent vertebral fractures, 11 fallers were categorized as having a hyperkyphosis, and 8 had a flexed posture.

In the univariate analyses (Table 1), a significant association was found between the Cobb angle and future falls ($p=0.04$); in addition, the presence of hyperkyphosis had a significant association with falls ($p=0.02$); the presence of ≥1 vertebral fracture had a trend toward significance ($p=0.06$). A flexed posture was not significantly related with prospective fall

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**Table 2: Univariate and multivariate regression analyses for fallers versus non-fallers during follow-up**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Non-fallers (n=38)</td>
<td>Fallers (n=13)</td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>79.7 (4.7)</td>
<td>78.0 (5.0)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>28 (74)</td>
<td>11 (85)</td>
</tr>
<tr>
<td>BMI in kg/m², mean (SD)</td>
<td>27.3 (3.9)</td>
<td>27.7 (4.3)</td>
</tr>
<tr>
<td>Charlson Comorbidity Index score, mean (SD)</td>
<td>1.3 (1.2)</td>
<td>1.6 (1.5)</td>
</tr>
<tr>
<td>Number of prescriptions, mean (SD)</td>
<td>5.4 (4.0)</td>
<td>7.1 (3.7)</td>
</tr>
<tr>
<td>MMSE score, median (range)</td>
<td>24 (15-30)</td>
<td>23 (13-28)</td>
</tr>
<tr>
<td>Hip replacement in history, n (%)</td>
<td>5 (13)</td>
<td>2 (15)</td>
</tr>
<tr>
<td>Frailty score, mean (SD)</td>
<td>1.0 (1.0)</td>
<td>1.6 (1.4)</td>
</tr>
<tr>
<td>Pluijm fall-risk-assessment score, mean (SD)</td>
<td>4.2 (4.5)</td>
<td>8.5 (6.1)</td>
</tr>
<tr>
<td>Increased fall risk (≥7 points Pluijm), n (%)</td>
<td>6 (16)</td>
<td>5 (39)</td>
</tr>
<tr>
<td>Time up and go in sec, mean (SD)</td>
<td>13 (5.4)</td>
<td>16 (6.4)</td>
</tr>
<tr>
<td>Vertebral fractures, n (%)</td>
<td>12 (32)</td>
<td>8 (62)</td>
</tr>
<tr>
<td>Cobb angle in degrees, mean (SD)</td>
<td>49 (13)</td>
<td>59 (16)</td>
</tr>
<tr>
<td>Hyperkyphosis, n (%)</td>
<td>17 (45)</td>
<td>11 (85)</td>
</tr>
<tr>
<td>Occipito-to-wall distance in cm, mean (SD)</td>
<td>4.2 (4.5)</td>
<td>6.2 (4.1)</td>
</tr>
<tr>
<td>Flexed Posture, n (%)</td>
<td>14 (37)</td>
<td>8 (62)</td>
</tr>
<tr>
<td>Nagelkerke R²</td>
<td></td>
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</tbody>
</table>

*Confidence Interval
incidents (p=0.13). The Pluijm fall-risk-assessment was associated with future falls in this cohort (p=0.02).

In the multivariate analysis (Table 2) with model A (all continuous or interval variables with with p<0.10)in the univariate analysis), only the Pluijm fall-risk-assessment was independently associated with falling in the follow-up period with an odds ratio of 1.16 (95% CI 1.01-1.32) for every point on the fall risk assessment (p=0.03). The Cobb angle in this model showed a trend towards significance for prospective falls in this cohort (p=0.07). Nagelkerke R² for this model was 34%.

In model B, the hypothesis was tested that the presence of hyperkyphosis, vertebral fractures, flexed posture, and/or increased fall-risk was independently associated with prospective fall incidents. The presence of hyperkyphosis was independently associated with future falls indicating that having a hyperkyphosis raises the odds for falling in the next year with 6.18 (95% CI 1.17-32.7; p=0.03). The presence of vertebral fractures or a flexed posture was not independently associated with prospective falls (p=0.12 and p=0.61 respectively). Neither was an elevated fall risk measured with the Pluijm fall-risk-assessment of ≥7 points significantly associated with prospective falls in this cohort (p=0.18). Nagelkerke R² was 29% for this model.

Discussion
The aim of this study was to determine the relationship between vertebral fractures, hyperkyphosis, flexed posture and prospective fall incidents in elderly patients. The most important finding was that hyperkyphosis (Cobb angle ≥50°) in elderly patients is independently associated with future fall incidents with an Odds Ratio of 6.18 (95% CI 1.17-32.74). We could not confirm a relationship between flexed posture and falls. Vertebral fractures and prospective falls had a trend towards significance (p=0.06).

However, it is remarkable that the presence of a hyperkyphosis had such a clear association with future falls, even in this small sample. This is in consistency with previous studies [14-17], although this is the first study to confirm falls prospectively. Due to the small sample in this study a clear estimation of the magnitude of our finding is not possible, reflected in the large confidence interval found. Hyperkyphosis can originate from vertebral fractures, although these are not the only cause, as seen in the non-significant relation in our cohort (p=0.24). This result is in accordance with the study of Schneider [28], which showed that vertebral fractures were apparent in 33%-55% of the patients with a hyperkyphosis in various age groups. Other causes for hyperkyphosis known from literature can be degenerative disc diseases, muscle weakness and genetic disorders such as Scheuermanns disease [11,29]. However, if vertebral fractures are present - in our cohort almost half of the patients with hyperkyphosis (13 out of 28) had also a vertebral fracture - patients should be treated with anti-osteoporosis medication to prevent subsequent fractures, and worsening of the thoracic kyphosis.

In our study the Nagelkerke R² was in the multivariate analyses models 29% and 34%, which is moderate. This indicates that there are other causes for falling than the presence
of hyperkyphosis in this patient group. Falling in patients with vertebral fractures may originate from various causes. Pain due to vertebral fractures can have negative impact on neuromuscular control [30] and individuals with vertebral fractures have an increased fear of falling [31], which has been shown to affect balance control [32] and may contribute to falls. Falling is multifactorial and many risk factors for falling have been identified [2], that could not all be measured in this study. However, the Pluijm fall-risk-assessment was done, since this instrument includes the main known risk factors for falling. In our cohort the Pluijm fall-risk-assessment was independently associated with prospective falls. However, the Pluijm-scale detected only 5 of the 13 fallers in the present study as having an increased fall risk. This can indicate that hyperkyphosis, which is not reflected in the Pluijm fall-risk-assessment, is an important – not yet identified - risk factor for future falls. Therefore, we recommend, based on our results, to implement assessing hyperkyphosis in fall-risk assessments, for instance by determining the thoracic Cobb angle on a spinal lateral radiograph.

Some limitations should be addressed. Because of the small sample size we could not could not give an indication of the magnitude of the independent association between hyperkyphosis and future falls. Furthermore in our cohort of patients aged about 80 years, the fall incidence was lower than the expected 30% [2]. The low fall incidence in our cohort can be the result of a successful visit to our geriatric outpatient clinic, where fall risk was analyzed and various advices were given to minimize the chance of falling according to the guidelines. Otherwise, although we gave a calendar and called patients every month, there might be underreporting: it is known that falls, even in healthy elderly, are easily forgotten [33].

In conclusion, older individuals with hyperkyphosis (Cobb angle ≥50°) are more likely to fall within the next year. We therefore recommend implementing hyperkyphosis in fall risk-assessments. Because vertebral fractures can contribute to hyperkyphosis and are usually the result of osteoporosis, falls in these patients raises the risk of a new fracture. The finding of vertebral fractures and particularly hyperkyphosis should alert physicians to start anti-osteoporotic therapy.
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