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ORIGINAL ARTICLE

Exploring the association between number, severity, location of fracture, and occiput-to-wall distance

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Abstract

Summary This study of women with a suspected vertebral fracture determined the association between vertebral fracture characteristics and posture. The number of fractures was associated with posture. Severity of fracture was associated with posture when adjusting for pain. Fracture characteristics explain some variability in posture in women with a suspected vertebral fracture.

Purpose Osteoporotic vertebral fractures are associated with increased morbidity and mortality. An accumulation of vertebral fractures may lead to forward head posture, which has been independently associated with mortality. It is unclear how fracture characteristics, including the number, severity, and location of fracture, contribute to occiput-to-wall distance (OWD).

Methods This was a cross-sectional secondary data analysis using baseline data from a randomized controlled trial, in community-dwelling women aged 65 years and older with a suspected vertebral fragility fracture. Lateral thoracic and lumbar spine radiographs were used to determine the number, location, and severity of fracture. Occiput-to-wall distance (OWD) was used to assess forward head posture. Pain during movement (0–10 scale) and age were considered as confounding variables. Multivariable regression models were used to evaluate relationships between fracture variables and OWD.

Results Participants ($n = 158$) were of mean age 75.9 (SD 6.5) years with a mean (SD) BMI = 26.7 (5.3) kg/m^2, OWD = 5.7 (4.6) cm, and number of fractures = 2.4 (2.4). In unadjusted analyses, the number of fractures ($B = 0.82$, 95% CI = 0.04, 1.59) was associated with OWD. When adjusting for pain, severity of fractures ($B = 1.08$, 95% CI = 0.001, 2.15) was independently associated with OWD. Location was not associated with OWD in any of the models.

Conclusions The number of fractures was significantly associated with OWD in the unadjusted model, explaining more of the variability in OWD than other fracture characteristics. Severity of fracture was associated with OWD in the adjusted model. However, pain may confound the relationship between OWD and fracture characteristics.

Keywords Vertebral fractures · Posture · Osteoporosis · Older adults · Hyperkyphosis

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Introduction

Vertebral fractures are the most common types of fragility fracture [1]. The prevalence of osteoporotic fractures increases with age, such that the prevalence of vertebral fractures in women aged 65 years and older is 50% [2–4]. Vertebral fractures are associated with secondary complications such as impaired pulmonary function, reduced quality of life, increased risk of future hip and vertebral fractures, chronic pain, and increased risk of mortality [5, 6]. Osteoporotic vertebral fractures may also lead to postural changes, particularly hyperkyphosis, defined as an excessive outward curvature of the thoracic spine [7]. Hyperkyphosis is more common in women than in men, and individuals with hyperkyphosis have a 1.4 times greater risk of mortality [8]. The presence of hyperkyphosis may contribute to pain [9] and balance impairment [10]. Clinical measures such as occiput-to-wall distance (OWD) provide an indirect measure of thoracic hyperkyphosis and can be used to screen individuals to determine who should be sent for X-ray. An OWD of 5 cm is indicative of hyperkyphosis and indicates concern for a vertebral compression fracture. Vertebral fracture risk (and therefore hyperkyphosis) is potentially modifiable via pharmacological therapy [11], or may be indirectly modified through exercise by increasing muscular strength, endurance, and reducing fall risk [12]. Understanding the inter-relationship between measures such as OWD and fractures may influence screening and treatment, specifically with allied health professionals working with individuals with osteoporosis. Understanding the association between OWD and vertebral fractures may influence a practitioner's decision to suggest imaging or the decision for patients to see a physician or specialist.

Vertebral fracture characteristics (i.e., severity, number, and location) have been associated with indirect measures of posture such as occiput-to-wall distance (OWD). For example, individuals with a grade 1, grade 2, and grade 3 vertebral fracture, based on the Genant fracture grading system, had an average OWD of 2.3 cm, 4.3 cm, and 8.1 cm, respectively [13]. The number of fractures has also been linked to an increased radiographically measured hyperkyphosis [14], without an increase in OWD [15]. Associations between hyperkyphosis and location of fracture have also been established [16]. Thoracic vertebral fractures are significantly associated with an increase in angle of hyperkyphosis and may contribute to postural changes more than fractures located in the thoracolumbar junction or lumbar vertebra [16]. Individuals with thoracic vertebral fractures had a greater kyphotic angle and OWD than those without thoracic vertebral fractures [13]. However, it may be the interaction between certain fracture characteristics that contributes more to hyperkyphosis than one variable independently. Siminoski [13] found that individuals with a thoracic vertebral fracture had an average of 1.9 fractures per person and had a greater kyphotic angle than those without thoracic fractures. Evidence of an interaction between severity and number of fractures suggests that individuals with severe vertebral deformities commonly sustain more severe incident vertebral fractures, with fracture severity predicting the risk of future vertebral fracture [5, 17, 18], and potentially contributing to postural changes. What remains unclear is whether increasing severity of hyperkyphosis is primarily due to the number of fracture, the severity of fracture(s), or the location of fractures, or whether it is due to an interaction among these characteristics.

Pain may be a confounding variable in the association between vertebral fractures and hyperkyphosis, as a potential cause or a consequence of hyperkyphosis [19]. Studies examining how vertebral fractures influence posture do not often account for confounding factors such as pain or age. Given that pain is potentially modifiable and could modify movement or compensatory postures, understanding its association with posture may influence the assessment and treatment of osteoporotic vertebral fractures. Further recognizing that our population is aging, it is important to understand the potential age-related adaptations in women with a suspected vertebral fracture. However, the number and severity of fracture, spinal degenerative changes, or muscle functioning, to name a few, may mediate the age association with vertebral fractures.

Given that vertebral fractures and postural changes are commonly associated with osteoporosis, it is unclear how fracture characteristics influence posture. Understanding the association between fracture number, severity, and location can provide insight into association with OWD and provide a foundation for predicting postural changes or vertebral fractures in patients with osteoporosis. The present study evaluated, in women with a vertebral fracture, whether there is an association between fracture characteristics and OWD, whether there is an interaction between fracture characteristics and OWD, and whether pain and age confound the associations.

Methods

Study design

This cross-sectional study was a secondary analysis of baseline data from the Build Better Bones with Exercise (B3E) Trial. B3E is a 1-year, multi-site (seven sites: St. Mary's Hospital-University of Waterloo; McMaster University; University of Toronto/Toronto General Hospital; Western University/ St. Joseph's Health Care; University of British Columbia; Broadmeadows Health Service in Australia and Royal Melbourne Hospital/University of Melbourne in Australia), randomized controlled trial of thrice-weekly home exercise compared to control (equal attention) in women aged 65 years or older with at least one vertebral fracture, [20]. The study protocol has been published (NCT01761084) [20]. Study participants were selected by treating physicians at each site. Physicians identified patients as having a vertebral fracture through X-rays taken within 6 months of being referred to participate in the study. If the participant did not already have an X-ray confirming vertebral fracture prior to study participation, physicians identified patients as having a potential vertebral fracture based on historical height loss.

Outcome measures

We used occiput-to-wall distance (OWD) (cm) to measure forward head posture, and used as a proxy measure for hyperkyphosis [21]. OWD is measured by having the participant stand with their heels and hips flat against a wall. The evaluator measures the distance from the occiput bone to the wall. OWD has a high correlation ($r = 0.902$, $p < 0.001$) with the Flexicurve measure of kyphosis, indicating strong concurrent validity to measure hyperkyphosis [22]. The sensitivity and specificity of OWD to detect prevalent thoracic fractures encountered in clinical practice were 41% and 92%, respectively, based on an OWD of greater than 5 cm and a Cobb angle greater than 50 degrees. An OWD greater than 5 cm is indicative of hyperkyphosis [23]. OWD has a strong inter-rater reliability, ICC = 0.92–9.04, Pearson $R = 0.84$ [24].

Fracture variables

All participants had lateral thoracic and lumbar spine radiographs in a hospital or clinic by an X-ray technician, unless the participant had a recent (within 6 months) X-ray as part of usual clinical care. A single musculoskeletal radiologist examined all radiographs to identify the number, location (from T4–L5), and the severity of vertebral fracture(s). The radiologist reviewing the X-rays is a musculoskeletal radiologist with fellowship training and 17 years of experience.

Severity

Severity of fracture was categorized based on the Genant vertebral fracture classification [25], which has a three-point scale classification (grade 1, grade 2, and grade 3). We classified only grade 2 (25–40% compressed) and grade 3 (greater than 40% compressed) fractures as morphometric fractures [26], due to the unreliability of classifying grade 1 fractures (20–25% compressed) [26]. Fracture severity was considered a categorical variable, such that participants were grouped into one of three categories: grade 0–1 fracture(s), one or more grade 2 fracture(s), or at least one grade 3 fracture. Therefore, individuals with multiple fractures of different severity would be grouped into the highest severity category, regardless of the number of fractures.

Location

We created three fracture location variables based on three regions of the spine: fractures occurring in mid-thoracic region (T4–8), fractures occurring between the thoracolumbar junction (T9–L1), and in the lumbar region (L2–L5). If an individual had a fracture in the location, it was coded with a 1 and if there was no fracture in the location it was coded with a zero. For example, a participant with a fracture at T8, T9, and L1 was coded: T4–T8 = 1, T9–L1 = 1, L2–L5 = 0. The location variable was binary, not categorical. This was done to try to avoid addressing the number and location of fractures in the same variable.

Number

Fracture number was determined as any vertebrae with a fracture as assessed radiographically, by a radiologist.

Confounding variables

Potential confounding variables that were considered for inclusion in the regression models were age and pain. Pain and age have been shown to contribute to variability in both vertebral fractures and OWD [27–29]. Pain was assessed using a VAS pain scale, which asked the participants to rate their pain related to their osteoporosis during movement, in the past week, on a scale from 0 to 10, with zero being no pain at all, and 10 being unbearable pain. Clinical or morphometric vertebral compression factors were not differentiated with respect to pain. Age was self-reported.

Statistical analysis

All analyses were performed with SPSS version 23 for Windows (IBM SPSS statistics, Armonk, NY). Descriptive statistics, such as age (years), body mass index (BMI, kg/m^2), height (cm), weight (kg), OWD (cm), number of fractures, number of medications and supplements, and number of comorbidities, were reported as means and standard deviations (SD).

The relationship between OWD and number of fractures, severity of fracture, T4–T8, T9–L1, and L2–L5, were assessed using multivariable regressions. Age and pain during movement were considered as potential confounding variables. No variables were removed based on p values as previous work suggests that when determining an association between variables, removing variables based on significance adds bias [30]. The unadjusted and adjusted models were presented. In the final models, a p value of < 0.05 was considered statistically significant. Due to the exploratory and ad hoc nature of this analysis, a parsimonious model was not generated.

Results

The current study used data from 158 individuals. Participants had a mean age of 76 (SD 6.5) years, with a mean BMI of 26.7 (SD 7.1) kg/m^2 (Table 1). The median number of fractures was 1 (quartile 1 = 1, quartile 3 = 3), with 142 (90%) of the participants having at least one grade 2 or higher fracture. Most of the fractures were in the grade 3 severity category (*n* = 95), and in the T9–L1 location (*n* = 107) (Figs. 1 and 2). It was not known how old the fractures were, or when the participant sustained the fracture. The participants had, on average, 2.5 (SD 2) comorbidities and were taking 5.3 (SD 4) medications and supplements, with 107 patients taking osteoporosis medication (Table 1). The three most common comorbidities in this population were osteoarthritis, high blood pressure, and heart disease. The average OWD was 5.7 cm (quartile 1 = 1, quartile 3 = 9) and 57% (*n* = 90) had an OWD of greater than 5 cm (Fig. 3).

The unadjusted multivariable regression model that included the number and severity of fracture, T4–T8, T9–L1, and L2-L5, was statistically significant accounting for 10% of the variance in OWD. The number of fractures was the only variable that was independently associated with OWD ($p < 0.05$), such that for every fracture, OWD increased by 0.82 cm. No other fracture characteristics were significantly associated with OWD (Table 2).

Table 1 Descriptive participant information based on 158 participants

Normally distributed variables	Mean (stdv)
Age (years)	75.9 (6.5)
Height (cm)	156.4 (7.1)
Weight (kg)	65.4 (14.1)
BMI	26.7 (5.3)
Number of comorbidities	2.5 (2.4)
Number of medications/supplements	5.3 (3.9)
Pain	4 (2.7)
Non-normally distributed variables	Median (Q1, Q3)
OWD (cm)	5.7 (1, 9)
Number of Fractures	1 (1, 3)
Categorical variables	*N* (%)
No fractures (*n*)	22 (13.9)
Severity of Fractures	
Grade 0–1 (*n*)	16 (10.1)
Grade 2 (*n*)	47 (29.7)
Grade 3 (*n*)	95 (60.1)
Location of fractures	
T1–T3	4 (2.5)*
T4–T8 (*n*)	65 (41.1)*
T9–L1 (*n*)	107 (67.7)*
L2–L5 (*n*)	57 (36.1)*

OWD occiput-to-wall distance, *BMI* body mass index

*An individual patient may have more than one fracture location reported

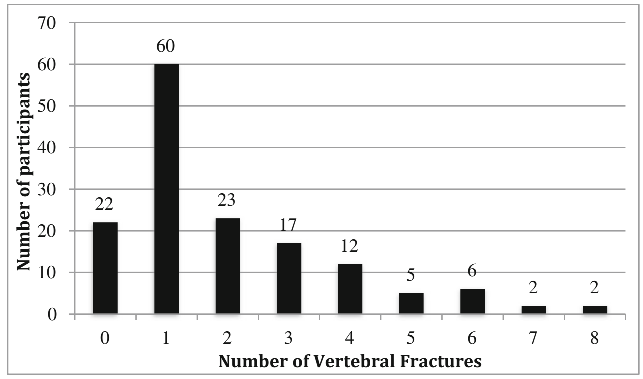

Fig. 1 Frequency of fractures, representing the number of participants with the number of fracture ranging from 0 to 8 fractures. Based on 158 participants

The adjusted multivariable regression model that accounted for age and pain during movement as confounding variables was statistically significant. This model accounted for 14% of the variability in OWD. Pain during movement and severity of fracture were independently associated with OWD. For every one-point increase in pain, OWD increased by 0.30 cm; and for every severity category increase, OWD increased by 1.08 cm. The number of fractures, location of fracture, and age were not independently associated with OWD in this model (Table 2).

Discussion

Our study revealed that the relationship between posture and vertebral fracture characteristics is not as straightforward as previously reported [11–13]. Individuals with pain are more likely to have increased OWD, but it is unclear whether OWD is a cause or a consequence of pain. Although some of the fracture characteristics were associated with OWD, the associations were weak, and explained little variability in OWD. Ultimately, the current study found that the number of fractures, and severity of fracture, was associated with OWD, but may be confounded by pain. However, there are likely other variables contributing to postural changes.

The variance explained by fracture characteristics was small. In women with a suspected vertebral fracture, the number of fractures was the only fracture variable positively associated with OWD. To date, two studies have found that there was a strong association between prevalent vertebral fractures and hyperkyphosis [13, 31]; whereas evidence from other studies suggest there is no association [15, 21, 23, 32, 33]. We hypothesized that there would be an association between fracture location and OWD, due to the known relationship between thoracic vertebral fractures and hyperkyphosis [16], as well as the high prevalence of fractures in the mid-thoracic vertebrae (T7–T8) and thoracolumbar junction (T11, T12, L1). However, we found no relationship between location of

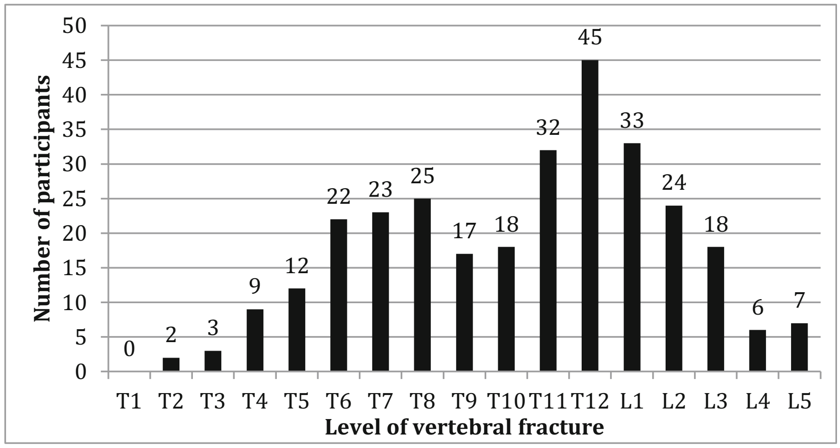

Fig. 2 Frequency of fractures by location of vertebral fracture, representing the number of participants with a fracture in each location from T1–L5. Based off 158 participants, however, some participants may have a fracture in more than one location

fracture and OWD, potentially because we used a categorical variable to describe location, and there was not enough power to detect a relationship. Severity of fracture and pain were independently associated with OWD in the adjusted model, without interaction terms, and interestingly, the number of fractures was no longer statistically significant in the adjusted model. It may be that our severity variable was not independently testing severity of fracture and may have accounted for the number of fractures as well. Delmas et al. [17] found that women with the most severe grade of vertebral fracture had a greater incidence of new vertebral fractures, compared with women with no fracture or mild or moderate severity fracture [17]. Currently, studies have looked at back pain in incident and prevalent vertebral fractures and found an association [34], but no studies have examined the relationship between pain and fracture severity. Other studies have reported an association between increased kyphotic angle and pain, [9] and kyphotic angle and severity of fracture [13]. The current study affirms there may be an association between severity of fracture, pain, and OWD in women with vertebral fractures; however, the amount of variance explained is relatively small (the adjusted model explained only an additional 4% of variance compared to the unadjusted model).

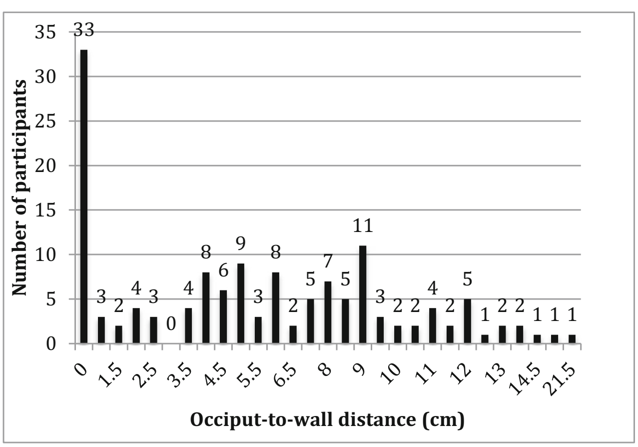

Fig. 3 Frequency of occiput-to-wall distance, representing the number of participants with the distance from their occiput bone to the wall ranging from 0 to 21.5 cm. Based on 158 participants

It appears that pain is related to OWD but has been overlooked in other studies examining the relationship between fracture characteristics and posture [35]. Previous studies have reported that hyperkyphosis is associated with pain and functional limitations [15, 36]. That said, the model that included pain explained only 4% more of the variability in OWD compared to the model with fracture characteristics only, which explained 10%, suggesting that neither fracture characteristics nor pain can explain why someone develops forward head posture. However, the average VAS pain during movement score in the current study was 4 (SD 2.7), which suggests mild-moderate pain in our women with a suspected vertebral fracture [37, 38].

Vertebral fractures, and possibly the resultant changes in posture, can contribute to secondary complications such as impaired vital capacity, reduced quality of life, and chronic pain [5, 6]. Exercise may be an intervention to mitigate pain in women with an osteoporotic vertebral fracture. There have been several exercise trials in women with an osteoporotic vertebral fracture, looking at pain as an outcome [19, 39]. There is very low-quality evidence of improvements in pain following exercise intervention. However, exercise does seem to have a small positive effect in studies with pain as an inclusion criterion [19, 39]. Future work should confirm whether exercise could influence pain in individuals with an osteoporotic vertebral fracture and hyperkyphosis.

Recognizing that little of the variability in OWD was explained by the fracture characteristics, other factors need to be explored to better understand determinants of changes in forward head posture in women with a suspected vertebral fracture. Balzini et al. [21] developed a clinical profile of individuals with mild, moderate, and severe forward head posture. They found that there was no difference in bone mineral density, but there were significant differences in muscular strength

Table 2 Association between fracture characteristics and OWD

	Unadjusted multivariable analyses			Adjusted multivariable analyses[a]		
	Beta coefficient	95% confidence interval	p value	Beta coefficient	95% confidence interval	p value
Number of fracture	0.82	(0.04,1.59)	0.04*	0.71	(− 0.06, 1.49)	0.07
Severity of fracture	0.83	(− 0.22,1.88)	0.12	1.08	(0.01, 2.15)	0.05*
T4–T8	− 1.14	(− 3.39,1.10)	0.32	− 1.06	(− 3.28, 1.16)	0.35
T9–L1	− 0.64	(− 3.08,1.80)	0.61	− 0.71	(− 3.13, 1.71)	0.56
L2–L5	− 0.48	(− 2.75,1.79)	0.68	− 0.57	(− 2.82, 1.68)	0.62

[a] The adjusted multivariable analysis was accounted for age and pain during movement as confounding variables

*$p < 0.05$

in the spinal extensors, ankle joint dorsiflexors, and plantar flexors, and significant shortening of the hip flexor and pectoralis major in the severe forward head posture group [21]. Forward head posture has also been associated with rounded shoulders [40], likely due to increased muscle shortening of the pectoralis major, and increased thoracic kyphosis [21, 40]. The aforementioned factors may be exacerbated by or due to habitual forward flexion from lifestyle, leisure, or work-related postures. Ankylosing spondylitis has also been linked to forward head posture, and increased hyperkyphosis [41], and additional pathologies like kyphoscoliosis. There is no literature on the effects of spinal arthritis on forward head posture but it could be another variable contributing to OWD. Only 40% of kyphosis was due to vertebral fractures, the remainder due to other pathology [42].

There were several limitations in this study worth mentioning. This study was designed to recruit individuals for exercise; therefore, there may be selection bias on which participants were willing to participate. OWD may not have enough sensitivity to detect subtle posture differences, such as morphological changes in the spine consistent with hyperkyphosis. However, OWD represents a safer, less expensive and burdensome measure of posture for use in a clinical setting and has been correlated with more direct measures of spinal curvature [16, 43]. Further, our study was cross-sectional in nature, and therefore we cannot make inferences related to causality. Future work should examine whether forward head posture or hyperkyphosis influences physical performance in individuals with vertebral fractures, or whether interventions to improve posture can also improve pain and physical performance, and should look at these associations longitudinally, to see how they progress. Our study did not account for other diseases that might contribute to OWD such as degenerative disc disease, osteoarthritis, kyphoscoliosis, or ankylosing spondylitis. Future studies should account for these diseases as potential confounding variables to the association between OWD and fracture characteristics. The distribution of our data was skewed, with most participants having one vertebral fracture and zero OWD. However, the finding that many women with prevalent fractures had no forward head posture has important implications for using OWD as a screening tool, such that it may miss many people with grade 2 or 3 fractures. No men were recruited to participate in this study, therefore the results are not be generalized to include men with osteoporosis.

In conclusion, the number or severity of fracture may be associated with OWD, but whether they were independent correlates depended on whether pain was included in the model, suggesting that pain during movement may be an important cause or consequence of postural changes in individuals with vertebral fractures. The amount of variance explained by any of the models was relatively small. Thus, the relationship between prevalent vertebral fractures and forward head posture as a surrogate of hyperkyphotic posture is not straightforward and may need to be explored in women with more severe forward head posture and multiple vertebral fractures.

Authors' contribution Christina M.D. Ziebart, Jonathan D. Adachi, Maureen C. Ashe, Robert R. Bleakney Angela M. Cheung, Jenna C. Gibbs, Keith D. Hill, David L. Kendler, Aliya A. Khan, Sandra Kim, Caitlin McArthur, Nicole Mittmann, Alexandra Papaioannou, Sadhana Prasad, Samuel C. Scherer, Lehana Thabane, John D. Wark, and Lora M. Giangregorio have all provided meaningful contributions to this manuscript.

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Compliance with ethical standards

Conflicts of interest None.

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