

Screening tool for identification of hip fractures in the prehospital setting

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Abstract

Objectives: This study aims to develop a screening tool that will help first responders identify patients with proximal femur fractures, commonly referred to as hip fractures, on site and direct these patients to hospitals with orthopaedic surgery services.

Study Design: Prospective survey.

Methods: Literature and expert opinion defined parameters for the Collingwood Hip Fracture Rule (CHFR) which predict a patient's likelihood of hip fracture. The study population included adults presenting to Collingwood General and Marine Hospital with lower extremity injuries between December 1, 2019 and March 10, 2020. Excluded patients had previous hip replacement, previous hip fracture on the side of the injury, or a high energy mechanism of injury. Patients were assessed with the CHFR before receiving x-ray imaging. The parameters were scored based on their predictive powers and analyzed by a receiver operating characteristic curve.

Results: The study included 101 patients (mean age 66.3 years), and 25.7% had a hip fracture confirmed on imaging. The sensitivity, specificity, positive predictive value, and negative predictive value helped score each parameter. Factors receiving 1 point are: age 65 to 79 years, female, mechanical fall, unable to weight-bear, knee pain. Factors receiving 2 points are: bruising at greater trochanter, age >80 years. Factors receiving 3 points are: pain with hip rotation, leg shortened and externally rotated. Score is the summation of all the factors' points. The receiver operating characteristic curve (0.953; *P* value < .0001) demonstrated scores of 7 had sensitivity:specificity of 84.6%:94.7%.

Conclusion: The CHFR screening tool score of 7 can be used by first responders in the prehospital setting to identify patients who sustain a hip fracture and make appropriate triage decisions. This will improve patient outcomes and decrease institutional costs.

Keywords: hip fracture, prehospital, proximal femur fracture, screening tool

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1. Introduction

1.1. Hip fracture incidence and burden

Proximal femur fracture, also known as hip fractures, continue to be an important social and economic burden. In 2008, the estimated lifetime risk for men and women was 4.6% and 12.1%, respectively.^[1] As the global population ages, the incidence of hip fracture is expected to increase alongside it. The annual Canadian healthcare costs related to hip fracture are estimated to increase to \$650 million by 2040.^[2,3]

1.2. Time to surgery

There is a correlation between hip fracture and time-to-surgery, which impacts patients' outcomes. The sooner the patient with a hip fracture undergoes surgical intervention, the less risk of perioperative morbidity and mortality.^[4-6] In over 65 year olds, more than 48 hours to surgery increases risk of hospital-acquired pneumonia, pressure ulcers and increases the length of hospital stays.^[6] Many studies have attempted to determine specific guidelines, with the resulting evidence demonstrating highly varied results.^[5] These studies have also demonstrated that delayed time to surgery represents a significant increase in healthcare costs for the hospital.^[5,7] The literature has no gold standard for time to surgery for proximal femur fracture patients; however, the province of Ontario has set a benchmark of 48 hours.^[8] The HIP ATTACK study demonstrated that the limit

for improved outcomes is at 24 hours to surgery.^[9] Rural communities face unique challenges in that some hospitals have orthopaedic surgery services and others do not. Our group has demonstrated that patients with hip fractures who present to a hospital that does not have orthopaedic surgery services, will likely experience a surgical delay for up to 24 hours.^[10] This translates to poorer outcomes for the patient.

1.3. Factors that increase the risk of hip fracture

There are many patient factors that contribute to hip fracture, including comorbid diseases, their associated drugs, and many nutritional and lifestyle factors.^[11] These aspects cannot be easily identified by first responders at the initial assessment.

1.4. Age over 65 years old and female sex

There are many patient factors that correlate with age that increase the risk of a patient having a hip fracture, including osteoporosis, frailty, decreased mobility, living in an institution, polypharmacy, etc.^[11] A study that compared Canadian and Swedish incidence rates showed that osteoporotic hip fracture past the age of 50 occurred at different age intervals between men and women. The Canadian data demonstrated that 90.6% of these fractures in women occurred over the age of 70 years old, while it only attributed to 79.8% for men.^[12]

In addition to age, female sex has been associated with an increased risk for hip fracture.^[11-14] This difference is commonly correlated to the incidence of osteoporosis as a result of hormonal changes postmenopause.^[13] One study of postmenopausal women demonstrated a significantly increased risk of osteoporotic fractures in women over the age of 70 years old, which interestingly did not correlate with the age of menopause onset.^[13]

1.5. Mechanical fall

A very common mechanism of injury that results in a hip fracture is a low energy fall, or a fall from standing height, in an individual over the age of 65 years old.^[15,16] This is also evident in the types of medications and diseases that seem to be positively correlated with an increased incidence of hip fracture. For example, individuals with motor impairment, such as in Parkinson disease, are at higher risk for falls and therefore higher risk of hip fracture.^[17,18]

1.6. Previous low energy fracture

A history of a previous low energy fracture is a strong indicator for hip fracture as an indicator of an individual's bone integrity and falls risk. Across the globe, various research studies support the increased incidence of hip fracture in the female population over 60 years old following distal radius, proximal humerus, or vertebral fractures.^[19-21] This finding is less evident with mixed populations, and there is some evidence that disputes this correlation.^[22]

A history of previous hip fracture has also been cited as a risk factor for subsequent contralateral fracture.^[23-26] The studies describe a significant increased risk of contralateral hip fracture in the first 2 years and a persisting risk for the subsequent 10 years.^[24-27] One study cited that 50.7% of contralateral fractures occurred within the 2 years following the first hip fracture.^[27] Although many of the population with second hip fracture had

increased risk due to increased age, female sex, poor mobility status, or living in an institution^[23,27-30]

1.7. Clinical signs

In the prehospital setting, where resources and time are limited, the most effective means of assessing a patient for hip fracture is a targeted physical examination. This screening tool will help to use key findings on examination that distinguish true hip fracture from conditions that present clinically similar, such as: dislocation, pelvic fracture, rheumatoid arthritis affecting the hip, septic hip joint, soft tissue injury, trochanteric bursitis, meralgia paresthetica, and pathology referred from the lumbar spine.^[11]

Key findings in a clinical examination include: bruising at the greater trochanter or patella (not present if acute), pain with hip movement (gentle roll of thigh elicits pain), pain at the knee (referred pain), unable to weight bear/tolerate axial load, and the affected leg may appear shorter, externally rotated, and abducted.^[11,31]

1.8. Rationale, hypothesis, significance

The Collingwood Hip Fracture Rule (CHFR) is the first clinical assessment screening tool for the identification of hip fracture. This tool is particularly valuable in the prehospital environment where patients could be triaged during transit, and, if indicated, redirected to hospitals with orthopaedic surgery services for surgical care. This strategy will improve patient outcomes by reducing time-to-surgery delay times. It will also significantly reduce costs to the healthcare system, by eliminating redundancy of admission, consultation, and investigations, as well as the time and cost associated with patient transfer. We anticipate that the CHFR, which will use a weighted score of clinical findings, will prove to be a highly specific and sensitive tool.

2. Methods

2.1. Selection of variables

This is a prospective survey study to examine the validity of patient factors and clinical findings to identify patients who likely have sustained a hip fracture. Variables were included in the survey if they were deemed relevant based on a review of the current literature or by the expert panel (See Supplemental Digital Content 1, Appendix 1, <http://links.lww.com/OTAI/A22>). The resultant survey is hereafter referred to as the CHFR survey (See Supplemental Digital Content 1, Appendix 2, <http://links.lww.com/OTAI/A22>).

2.2. Study design and participants

The study data collection period began on December 1, 2019 and finished on March 10, 2020 and included 101 patients. This time frame of 3.5 months was shorter than expected as a result of the COVID-19 pandemic. The CHFR survey was used in the emergency department of Collingwood General and Marine Hospital to assess all patients experiencing acute pain in the groin, hip, buttock, or knee (referred pain) after a low energy mechanism of injury.^[11] The exclusion criteria was all patients with previous hip replacement or fracture on the same side as the presenting injury, a high energy mechanism of injury, or a multitrauma injury. By completing the survey, physicians implied consent to participate in the study.

2.3. Study measures

The initial patient assessment and demographic data were collected by the orthopaedic technologist, and emergency room physicians. The data collected included: patient hospital ID, sex, age, mechanism of injury, previous hip fracture, bruising over the greater trochanter or the patella, pain with hip rotation, weight-bearing status, knee pain, previous hip replacement, or if the affected leg was shortened and externally rotated (See Supplemental Digital Content 1, Appendix 2, <http://links.lww.com/OTAI/A22>). Another recorded value was the data collector's impression of the patient and if they suspected a hip fracture. The final radiographic assessment was collected by the orthopaedic technologist.

2.4. Confounding factors and bias control

Possible confounding factors such as patient sex, age, and mechanism of injury were documented so that statistical analysis could determine the degree of influence they may have. The exclusion criteria included high energy mechanism of injury, previous hip replacement, or fracture on affected side and aimed to minimize the degree of confounding factors in this study. To minimize confirmation bias, the individual who completed statistical analysis was not involved in the data collection or in the process of writing the final manuscript. The study may demonstrate some sampling bias, as the population was determined by using the population that was transported to Collingwood General and Marine Hospital. As a result, this study sample may not represent a true random sample of the population.

2.5. Study size

The final study size was determined by the total number of patients who presented to CMGH with low energy mechanical falls during the study period.

2.6. Statistical analysis

Data analysis was performed by the research assistant, who was not directly involved in the data collection. Statistical analysis was performed using SPSS version 24 (IBM Corp, Armonk, New York). The demographic data is presented with means (standard deviations and ranges) for continuous variables and frequencies for categorical variables. The statistical analysis included calculation of the sensitivity, specificity, positive predictive value (PPV), and negative predictive value associated with each of the parameters of the CHFR. Once established, the variables were allotted a weighting and the patients' answers were given a score. From these scores, a receiver operating characteristic (ROC) curve was plotted to identify the optimal total score that elicits the highest levels of sensitivity and specificity.

3. Results

Of the CMGH population of patients, 3 were excluded by the exclusion criteria. The patients who were assessed (N=101) demonstrated a mean age of 66.2 years old, with a range of 15 to 95 years old. The patient population was 68% female and 32% male, with average ages of 67.45 and 63.78 years, respectively (Table 1).

Within the study population 25.74% of the patients had a confirmed hip fracture on radiographic analysis. In this cohort

Table 1

Summary of patient demographics.

Patient demographics	
Hips, n	101
Mean age, yrs (SD; range)	66.29 (20.39; 15–95)
Male, yrs (SD; range)	63.78 (18.73; 15–88)
Female, yrs (SD; range)	67.45 (21.14; 20–95)
Gender, n (%)	
Male	32 (31.68)
Female	69 (68.32)
X-ray results, n (%)	
Hip fracture	26 (25.74)
Male	9 (34.62)
Female	17 (65.38)
No hip fracture	75 (74.26)

the most prevalent characteristics and clinical signs included mechanical fall, not weight bearing and age >65 years. There were zero patients with previous hip fracture or bruising at the patella and therefore cannot be commented on further. See Supplemental Digital Content 1, Appendix 3, <http://links.lww.com/OTAI/A22>. Age was stratified into 5-year categories of >65 years, >70 years, >75 years, >80 years, and >85 years, which accounted for approximately 85%, 80%, 70%, 60%, and 50% of the total number of fractures, respectively. This stratification helped to determine significantly influential age cutoffs beyond the >65 years cited by osteoporotic guidelines. See Supplemental Digital Content 1, Appendix 3, <http://links.lww.com/OTAI/A22>.

The sensitivity, specificity, PPV, and negative predictive value were calculated for each parameter. In this cohort the most sensitive characteristics and clinical signs included mechanical fall at 100%, not weight bearing at 88.5%, and age >65 years at 84.6%. The parameters with the highest specificity included leg shortened and externally rotated at 100%, bruising at the greater trochanter at 96.0%, and pain with hip rotation at 93.3%.

From the validity analysis, the parameters were included based on their negative predictive values, and given a score based on their positive predictive values. Any parameters that PPV scored >80%, >45%, and >0% received scores of 3, 2, and 1, respectively (see Table 2 and Table 3).

The resultant scoring system demonstrates a range of scores from 0 to 13. This system was applied to the data from the study population and total scores were calculated for each individual. The data was then plotted on a ROC curve that demonstrates an area under the curve of 0.953 (CI – 0.905 – 1.000) with a *P* value of <.0001 (Fig. 1). The cut-off score of 3 and above demonstrated sensitivity and specificity of 100% and 34.7%, respectively. The cut-off score of 7 and above demonstrated sensitivity and specificity of 84.6% and 94.7%, respectively.

4. Discussion

4.1. Contribution of individual factors within the CHFR

The parameters of the test were appraised and assigned a value as a result of their validity testing (i.e., sensitivity, specificity, etc). Individuals at increased age who have had a mechanical fall and are unable to weight bear, are the patients most at risk for hip fracture. Therefore, these parameters are highly sensitive but have variable specificity. The ages of hip fracture patients, once organized into 5-year groupings, demonstrated significantly more risk attributed to the >80 years age group. It is possible that

Table 2
Analysis of CHFR parameters.

Values	Sensitivity, n (%)	Specificity, n (%)	Positive predictive value (%)	Negative predictive value (%)
Female sex	17 (65.4)	23 (30.7)	24.6	71.9
Age >65 yrs	22 (84.6)	40 (53.3)	38.6	90.9
Mechanical fall	26 (100)	7 (9.3%)	27.7	100.0
Previous hip fracture	—	—	—	—
Bruising at greater trochanter	5 (19.2)	72 (96.0)	62.5	77.4
Bruising at patella	—	—	—	—
Pain with hip rotation	20 (76.9)	70 (93.3)	80.0	92.1
Not weight bearing	23 (88.5)	16 (21.3)	28.0	84.2
Leg shortened and externally rotated	17 (65.4)	75 (100)	100	89.3
Pain at knee	11 (42.3)	34 (45.3)	21.2	69.4
* Age >70 yrs	21 (80.8)	43 (57.3)	39.6	89.6
* Age >75 yrs	18 (69.2)	47 (62.7)	39.1	85.5
* Age >80 yrs	16 (61.5)	58 (77.3)	48.5	85.3
* Age >85 yrs	11 (42.3)	65 (86.7)	52.4	81.3

* Parameters derived from age analysis.

this age category represents the timing when the overall frailty of patients reaches a threshold point, evident by the increased prevalence of nonvertebral, nonhip fracture in this population.^[32] Previous studies have demonstrated no significant difference in fall occurrence between age groups <80 years versus >80 years.^[33]

Interestingly, a study from Italy demonstrated that patient cohorts younger than 84 years old were demonstrating a decline in prevalence of hip fractures.^[34] Historically, there was an increased prevalence of fragility fractures past the age of 65 years old.^[12] Our study echoes the findings of the Italian study by demonstrating a postponed age of increased risk. This shift may be as a result of the changing demographics of the early geriatric population. There are some arguments for improved overall health in this demographic compared with earlier generations as well as better understanding of risk factors and medications to manage bone integrity.^[35]

The highly specific parameters of the test included pain with hip rotation and externally rotated and shortened. Patients with noticeable deformity such as a shortened and externally rotated leg may be an obvious hip fracture patient. In contrast, pain with hip rotation will be highly specific for both displaced and nondisplaced hip fractures.

Parameters with variable evidence included pain at knee and bruising at the greater trochanter. Both parameters, while commonly accepted clinical signs of hip fracture, are variably present in hip fracture patients. Patients who experience this pain at the knee may not be able to differentiate the pain and may just

experience pain in the whole upper leg. Similarly, unless there has been a disruption of a major blood vessel, bruising at the greater trochanter or the knee requires time to form and may not be present if the injury is acute.

4.2. Characteristics without data

There was limited evidence for previous hip fracture and bruising at the knee. A Canadian study previously demonstrated that there was a 10-year increased risk for a second hip fracture after the index injury.^[25] Similarly, many studies have demonstrated the relevance of previous vertebral and distal radius fragility fractures as clear indicators of increased risk.^[14,19,20,32] While there are known correlations between previous fragility fractures and secondary hip fracture, there is limited evidence from our data set to include the parameter in the scoring or appraise the parameter for scoring.

Table 3
Summary of CHFR tool proposed scoring system.

Values	Score
Age >65 yrs	1
Age >80 yrs	2
Mechanical fall	1
Previous hip fracture	*
Bruising at greater trochanter	2
Bruising at patella	*
Pain with hip rotation	3
Not weight bearing	1
Leg shortened and externally rotated	3
Pain at knee	1

* Relationship to hip fracture unclear.

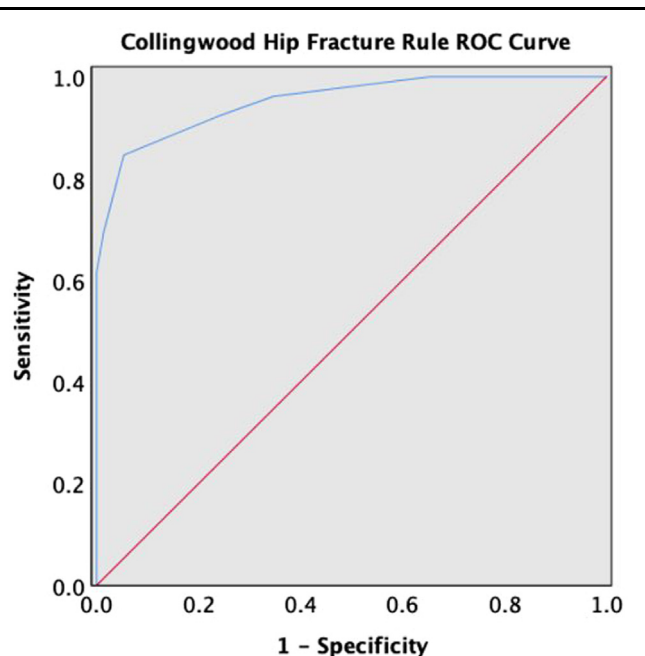


Figure 1. Receiver operator characteristic (ROC) curve demonstrating the relationship between the total scores from the Collingwood Hip Fracture Rule and x-ray identified hip fractures.

4.3. ROC analysis

The ROC curve demonstrates a statistically significant relationship between the scored CHFR and the outcome of radiologically identified hip fracture. This demonstrates a clear internal validation of the CHFR and its use to correctly identify patients with hip fracture from clinical and situational factors.

The CHFR cut-off score of 3 demonstrates a low specificity of 34.7%; it also demonstrates the threshold for patients who most likely have not sustained a fracture. This score will allow first responders to transport patients without a hip fracture to the closest hospital and streamline their care pathway. This score will aid in minimizing time and costs associated with rerouting the ambulance and orthopaedic service involvement.

Contrastingly, a score of 7 demonstrates high levels of both sensitivity and specificity. This cutoff will support a first responder's decision to reroute toward an orthopaedic hospital. This score will also help relay the degree of certainty regarding the likelihood of fracture to the hospital they will present to. This series of events will allow for a streamlined care pathway as the orthopaedic service can prepare for the patient's arrival accordingly.

4.4. Next steps

As a continuation of the pilot study, a full-scale study will be performed to help minimize bias and increase the power of the data. The next step is to implement the screening tool within the intended environment, the Emergency Medical Services, to test the external validity. Additionally, the clinical variables that have unclear or insufficient evidence in this survey must be assessed for importance and the survey consequently refined. Therefore, as a part of the main study, the situational characteristics and clinical signs can be assessed by univariate and recursive partitioning analyses.

4.5. Strengths and limitations

Some strengths of the study are that it is a novel use of a fracture-screening tool as a modification to traditional first responder services. The use of such a tool in the community demonstrates excellent potential to improve the institutional risks and costs associated with hip fracture patients and their morbidity and mortality.

The limitations of this study include a small sample size, and the bias associated with a convenience population sample. Additionally, the results from this preliminary data set have outlined room for improvement on the survey as not all included factors had data.

5. Conclusion

In summary, the Collingwood Hip Fracture Rule screening tool has been demonstrated as a valid clinical screening tool for identifying patients with hip fractures. Once implemented in the prehospital setting, a score of 7 can be used by first responders to identify patients who likely sustained a hip fracture and make appropriate triage decisions. This strategy will improve patient outcomes by reducing time-to-surgery delay times. It will also significantly reduce costs to the healthcare system, by eliminating redundancy of admission, consultation, and investigations, as well as the time and cost associated with patient transfer.

References

- Hopkins RB, Pullenayegum E, Goeree R, et al. Estimation of the lifetime risk of hip fracture for women and men in Canada. *Osteoporos Int*. 2012;23:921–927.
- Bhandari M, Swiontkowski M. Management of acute hip fracture. *N Engl J Med*. 2017;377:2053–2062.
- Cummings SR, Rubin SM, Black D. The future of hip fractures in the United States. Numbers, costs, and potential effects of postmenopausal estrogen. *Clin Orthop Relat Res*. 1990;163–6.
- Anthony CA, Duchman KR, Bedard NA, et al. Hip fractures: appropriate timing to operative intervention. *J Arthroplasty*. 2017;32:3314–3318.
- Kempnaers K, Van Calster B, Vandoren C, et al. Are the current guidelines for surgical delay in hip fractures too rigid? A single center assessment of mortality and economics. *Injury*. 2018;49:1169–1175.
- Sasabuchi Y, Matsui H, Lefor AK, et al. Timing of surgery for hip fractures in the elderly: a retrospective cohort study. *Injury*. 2018;49:1848–1854.
- Dy CJ, McCollister KE, Lubarsky DA, et al. An economic evaluation of a systems-based strategy to expedite surgical treatment of hip fractures. *J Bone Joint Surg Am*. 2011;93:1326–1334.
- Ontario HQ. Information and Data Brief: Hip Fracture. Care for people with fragility fractures. In: Ontario HQ, editor. 2016. <https://www.hqontario.ca/portals/0/documents/evidence/quality-standards/>.
- Borges FK, Bhandari M, Patel A, et al. Rationale and design of the HIP fracture Accelerated surgical Treatment And Care track (HIP ATTACK) Trial: a protocol for an international randomised controlled trial evaluating early surgery for hip fracture patients. *BMJ Open*. 2019;9:e028537.
- Cheng OA, O.; Hin Law, N. Comparing hip fracture to surgery time between hospitals with and without orthopaedic services. Publication Pending.
- Carriero FP, Christmas C. In the clinic. Hip fracture. *Ann Intern Med*. 2011;155:ITC6-1-ITC6-15; quiz ITC6-16. doi: 10.7326/0003-4819-155-11-201112060-01006.
- Lam A, Leslie WD, Lix LM, et al. Major osteoporotic to hip fracture ratios in canadian men and women with Swedish comparisons: a population-based analysis. *J Bone Miner Res*. 2014;29:1067–1073.
- Banks E, Reeves GK, Beral V, et al. Hip fracture incidence in relation to age, menopausal status, and age at menopause: prospective analysis. *PLoS Med*. 2009;6:e1000181.
- Berry SD, Kiel DP, Colon-Emeric C. Hip fractures in older adults in 2019. *JAMA*. 2019;321:2231–2232.
- Leavy B, Byberg L, Michaelsson K, et al. The fall descriptions and health characteristics of older adults with hip fracture: a mixed methods study. *BMC Geriatr*. 2015;15:40.
- Schick S, Heinrich D, Graw M, et al. Fatal falls in the elderly and the presence of proximal femur fractures. *Int J Legal Med*. 2018;132:1699–1712.
- Bhattacharya RK, Dubinsky RM, Lai SM, et al. Is there an increased risk of hip fracture in Parkinson's disease? A nationwide inpatient sample. *Mov Disord*. 2012;27:1440–1443.
- Nystrom H, Nordstrom A, Nordstrom P. Risk of injurious fall and hip fracture up to 26 y before the diagnosis of Parkinson Disease: nested case-control studies in a nationwide cohort. *PLoS Med*. 2016;13:e1001954.
- Bozkurt HH, Atik OS, Tokgoz MA. Can distal radius or vertebra fractures due to low-energy trauma be a harbinger of a hip fracture? *Eklem Hastalik Cerrahisi*. 2018;29:100–103.
- Johnson NA, Stirling ER, Divall P, et al. Risk of hip fracture following a wrist fracture: a meta-analysis. *Injury*. 2017;48:399–405.
- Clinton J, Franta A, Polissar NL, et al. Proximal humeral fracture as a risk factor for subsequent hip fractures. *J Bone Joint Surg Am*. 2009;91:503–511.
- Daruwalla ZJ, Huq SS, Wong KL, et al. Hip fractures, preceding distal radius fractures and screening for osteoporosis: should we be screening earlier? A minimum 10-year retrospective cohort study at a single centre. *Osteoporos Int*. 2016;27:361–366.
- Mazzucchelli R, Perez-Fernandez E, Crespi N, et al. Second hip fracture: incidence, trends, and predictors. *Calcif Tissue Int*. 2018;102:619–626.
- Omsland TK, Emaus N, Tell GS, et al. Ten-year risk of second hip fracture. A NOREPOS study. *Bone*. 2013;52:493–497.
- Sobolev B, Sheehan KJ, Kuramoto L, et al. Risk of second hip fracture persists for years after initial trauma. *Bone*. 2015;75:72–76.

26. Wongtriratanachai P, Chiewchantanakit S, Vaseenon T, et al. Second hip fractures at Chiang Mai University Hospital. *J Med Assoc Thai.* 2015;98:201–206.
27. Lau JC, Ho KW, Sadiq S. Patient characteristics and risk of subsequent contralateral hip fracture after surgical management of first fracture. *Injury.* 2014;45:1620–1623.
28. Juhasz K, Boncz I, Patczai B, et al. Risk factors for contralateral hip fractures following femoral neck fractures in elderly: analysis of the Hungarian nationwide health insurance database. *Eklek Hastalik Cerrahisi.* 2016;27:146–152.
29. Liu S, Zhu Y, Chen W, et al. Risk factors for the second contralateral hip fracture in elderly patients: a systematic review and meta-analysis. *Clin Rehabil.* 2015;29:285–294.
30. Zhu Y, Chen W, Sun T, et al. Meta-analysis of risk factors for the second hip fracture (SHF) in elderly patients. *Arch Gerontol Geriatr.* 2014;59:1–6.
31. LeBlanc KE, Muncie HL Jr, LeBlanc LL. Hip fracture: diagnosis, treatment, and secondary prevention. *Am Fam Physician.* 2014;89:945–951.
32. Center JR. Fracture burden: what two and a half decades of dubbo osteoporosis epidemiology study data reveal about clinical outcomes of osteoporosis. *Curr Osteoporos Rep.* 2017;15:88–95.
33. Gratzka SK, Chocano-Bedoya PO, Orav EJ, et al. Influence of fall environment and fall direction on risk of injury among pre-frail and frail adults. *Osteoporos Int.* 2019;30:2205–2215.
34. Giannini S, Sella S, Rossini M, et al. Declining trends in the incidence of hip fractures in people aged 65 years or over in years 2000–2011. *Eur J Intern Med.* 2016;35:60–65.
35. Kannus P, Niemi S, Parkkari J, et al. Nationwide decline in incidence of hip fracture. *J Bone Miner Res.* 2006;21:1836–1838.