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Risk of Musculoskeletal Injuries, Fractures, and Falls in Medicare Beneficiaries With Disorders of Binocular Vision

Stacy L. Pineles, MD, MS, **Michael X. Repka, MD, MBA**, **Fei Yu, PhD**, **Flora Lum, MD**, and **Anne L. Coleman, MD, PhD**

Jules Stein Eye Institute, Department of Ophthalmology, UCLA (University of California, Los Angeles) (Pineles, Yu, Coleman); Wilmer Eye Institute, the Johns Hopkins University School of Medicine, Baltimore, Maryland (Repka); H. Dunbar Hoskins Jr, MD Center for Quality Eye Care, Foundation of the American Academy of Ophthalmology, San Francisco, California (Lum); Fielding School of Public Health, Department of Epidemiology, UCLA (Coleman)

Abstract

Importance—Disorders of binocular vision are increasingly prevalent among fee-for-service Medicare beneficiaries 65 years or older. Visual impairment is a recognized risk factor for fractures. Despite the association of visual impairment and fracture risk, to our knowledge, no study has examined the influence that disorders of binocular vision (strabismus, amblyopia, diplopia, and nystagmus) may have on musculoskeletal injury and fracture risk in the elderly population.

Objective—To evaluate associations between disorders of binocular vision and musculoskeletal injury, fracture, and falls in the elderly.

Design, Setting, and Participants—A retrospective study of 10-year (2002-2011) musculoskeletal injury, fracture, or fall prevalence in a 5% random sample of Medicare Part B fee-for-service claims for beneficiaries with disorders of binocular vision. Participants included Medicare beneficiaries living in the general community who were 65 years or older with at least 1 year of Medicare Part B enrollment.

Exposures—Diagnosis of a disorder of binocular vision.

Corresponding Author: Anne L. Coleman, MD, PhD, Jules Stein Eye Institute, Department of Ophthalmology, UCLA, 100 Stein Plaza, Los Angeles, CA 90095 (colemana@ucla.edu).

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Study concept and design: Pineles, Repka, Yu, Coleman.

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Main outcomes and measures—Ten-year prevalence of musculoskeletal injury, fracture, or fall in individuals with and without disorders of binocular vision. Analyses were adjusted for age, sex, race/ethnicity, region of residence, systemic and ocular comorbidities, and duration of follow-up.

Results—There were 2 196 881 Medicare beneficiaries identified. Of these, 99 525 (4.5%) had at least 1 reported disorder of binocular vision (strabismus, 2.3%; diplopia, 2.2%; amblyopia, 0.9%; and nystagmus, 0.2%). During the 10-year study period, there were 1 272 948 (57.9%) patients with documented musculoskeletal injury, fracture, or fall. The unadjusted odds ratio (OR) for the association between disorders of binocular vision and any of the 3 injury types was 2.23 (95% CI, 2.20-2.27; $P < .001$). The adjusted OR was 1.27 (95% CI, 1.25-1.29; $P < .001$).

Conclusions and Relevance—Medicare beneficiaries with a disorder of binocular vision have significantly higher odds of sustaining a musculoskeletal injury, fracture, or fall. This finding is an important step forward in understanding and developing strategies to prevent these injuries, which are associated with high morbidity in the elderly.

Musculoskeletal injuries, fractures, and falls are a significant cause of morbidity and mortality in elderly individuals.[1,2] Visual impairment has been shown[3-7] to be associated with an increased risk of fractures in this population. Although studies have demonstrated an increased risk of fractures in older patients with visually significant cataract,[8] glaucoma,[7] and age-related macular degeneration (AMD),[9] to our knowledge, there has not been a study evaluating whether disorders of binocular vision may be associated with increased risk of musculoskeletal injuries, fractures, or falls.

There are several reasons why disorders of binocular vision may be associated with an increased risk of musculoskeletal injuries, fractures, or falls. First, disorders of binocular vision are often associated with diminished depth perception and could therefore contribute to falls and resultant injuries. In addition, the presence of diplopia or visual confusion can place patients at risk for injuries owing to their difficulty in fixating on an object, in pursuing moving objects, and in perceiving spatial relationships.

Given that the prevalence of strabismus has been increasing over the past decade in the Medicare-aged population,[10] it is important to evaluate whether disorders of binocular vision may be associated with an increased risk of musculoskeletal injury, fractures, or falls in elderly patients. The purpose of this study was to examine the association between a disorder of binocular vision and musculoskeletal injury, fractures, and falls among Medicare-aged beneficiaries.

Methods

This study was approved by the institutional review board at UCLA. A waiver of informed consent was provided as part of the institutional review board process. All research procedures adhered to the tenets of the Declaration of Helsinki. The 2002-2011 Denominator and Physician/Supplier Medicare Part B files for a 5% random sample of beneficiaries were obtained from the Centers for Medicare & Medicaid Services. Only patients who had at least 1 year of coverage were included in this study. The following

additional exclusion criteria were applied: age younger than 65 years, residence outside the United States, lack of Medicare Part B fee-for-service coverage, and Medicare Advantage (Part C) coverage. Claims data under Medicare Advantage (Part C) are not collected by the Centers for Medicare & Medicaid Services; therefore, these data are not available for analysis. To capture the full medical history of each beneficiary, patients with Medicare Advantage coverage were excluded from this analysis regardless of their available data in the Medicare Part B database. Within the random 5% sample of patients, those with diagnosis codes for disorders of binocular vision were extracted from the Physician/Supplier Medicare Part B files using the *International Classification of Disease, Ninth Revision, Clinical Modification* (*ICD-9-CM*)[11] diagnosis codes. Patients with the following diagnoses were considered to have disorders of binocular vision: strabismus (378.0X, 378.1X, 378.2X, 378.3X, 378.5X, 378.6X, 378.7X, 378.8X, and 378.9), amblyopia (368.0X), diplopia (368.2), other disorders of binocular vision (368.3X), nystagmus (379.5X), and ocular motor cranial nerve injuries (951.0, 951.1, and 951.3). To determine the prevalence of musculoskeletal injury, fractures, and falls, the occurrence of these injuries was identified by *ICD-9-CM* diagnosis codes and *Current Procedural Terminology*[12] codes for surgical services (eTable 1 in the Supplement).

Other baseline characteristics were enumerated and evaluated as potential confounding variables for the association between disorders of binocular vision and musculoskeletal injury, fractures, and falls. Hip fractures were specifically examined given the likelihood that they are associated with falls in the elderly. Demographic information included age, sex, self-reported race/ethnicity, and US region of residence. Overall systemic health was determined by the Charlson Comorbidity Index (CCI) score, [13] which assigns patients a score between 0 and 6 on the basis of the likelihood of mortality secondary to age and the presence or absence of selected systemic diseases during the subsequent 10 years. The CCI stratification was based on the original CCI study analysis, [13] which classified 1-year mortality based on CCI subgroups of 0, 1 or 2, 3 or 4, and 5 or greater. A higher score is associated with an increased risk of mortality. The following diseases are included in the CCI: myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, cirrhosis, hepatic failure, immunosuppression, diabetes mellitus, hemiplegia or paraplegia, chronic renal disease, malignant neoplasms, multiple myeloma or leukemia, lymphoma, metastatic solid tumors, and AIDS. In addition to these diseases included in the CCI, there are other systemic conditions that would reasonably be associated with musculoskeletal injury, fracture, or fall risk. These conditions were also included: osteoporosis, hyperthyroidism, hyperparathyroidism, glaucoma, cataract, AMD, diabetes with ophthalmic manifestations, Parkinson disease, and the presence of a physically limiting condition. These comorbidities were identified using the relevant *ICD-9-CM* codes (eTable 2 in the Supplement). All comorbidities were considered potential covariates and were included in the statistical analysis.

Descriptive statistics were used for the baseline characteristics of the Medicare-aged fee-for-service population with at least 1 year of follow-up, as well as for individuals with the diagnosis of a disorder of binocular vision. Beneficiaries with a diagnosed disorder of

binocular vision were compared with those without these diagnoses, using χ^2 tests to evaluate the differences in age, sex, race, ethnicity, and US region of residence.

A multivariable logistic regression model was used to estimate the association between a disorder of binocular vision and musculoskeletal injuries, fractures, or falls at any time during the 10-year follow-up, adjusting for the following potential confounders: age, sex, race/ethnicity, US region of residence, CCI score, osteoporosis, hyperthyroidism, hyperparathyroidism, glaucoma, cataract, AMD, diabetes with ophthalmic manifestations, Parkinson disease, presence of a physically limiting condition, and duration of follow-up. To account for possible confounding from multiple diagnoses (ie, strabismus and diplopia or strabismus and amblyopia), a second multivariable logistic regression was performed similarly to the model described above but with the inclusion of the following diagnoses as independent variables: any form of strabismus (ie, esotropia, exotropia, and hypertropia), diplopia, nystagmus, amblyopia, and disorders of binocular vision. All statistical analyses were conducted using SAS, version 9.3 (SAS Institute Inc).

Results

A total of 2 196 881 Medicare beneficiaries with at least 1 year of coverage were included in the 5% sample in 2002-2011 (Table 1). The median duration of Part B coverage during the study period was 6 years (range, 1-10 years). Of the cohort, 42.4% were male (n = 932 207). Most were white (1 895 012 [86.3%]). The median age was 70 years, with the largest group aged 65 to 69 years (1 081 421 [49.2%]). A disorder of binocular vision was present in 99 525 (4.5%) of the patients. Table 2 reports the diagnoses and distribution of those subtypes of disorders of binocular vision. Strabismus and diplopia were the most common disorders. Comparisons of demographic characteristics of patients with and without a diagnosed disorder of binocular vision are reported in Table 3. The patients with disorders of binocular vision were older, were more often male, were more often white, and had more comorbidities than did those without disorders of binocular vision. Disorders of bin-ocular vision were also found more commonly in the East and Midwest compared with the South and West.

Overall, the 10-year prevalence of any musculoskeletal injury, fracture, or fall was 57.9% for the entire sample (1 272 948 of 2 196 881). The prevalence of any musculoskeletal injury, fracture, or fall was 74.9% (74 504 of 99 525) in patients with disorders of binocular vision and 57.1% (1 198 444 of 2 097 356) in patients without disorders of binocular vision (Table 4).

The unadjusted and adjusted odds ratios (ORs) for an association between musculoskeletal injury, fracture, or fall and the presence of a disorder of binocular vision were calculated (Table 4). After accounting for confounding variables, a significant association remained between disorders of binocular vision and musculoskeletal injuries, fractures, and/or falls.

Table 5 reports the adjusted ORs for the 10-year prevalence of musculoskeletal injury, fracture, or fall for commonly diagnosed disorders of binocular vision. We found significant associations between each diagnosis of disorder of binocular vision and musculoskeletal

injury, fracture, or fall. A frequent type of disorder of binocular vision was diplopia, which had a higher risk (OR, 1.36), than did many other disorders of binocular vision.

Discussion

We reviewed a 5% random sample of fee-for-service Medicare beneficiaries 65 years or older to determine whether there was an association between the presence of a disorder of binocular vision and musculoskeletal injury, fracture, or fall. We found a 27% higher risk of musculoskeletal injury, fracture, or fall in patients with a disorder of binocular vision after accounting for potential confounders. This statistically, as well as clinically, significant association remained when each type of injury was evaluated separately.

Impaired binocular vision may diminish patients' ability to avoid or negotiate obstacles or hazards in their environment while walking, thus leading to musculoskeletal injury, fracture, or fall. This finding agrees with those of several smaller studies[6,14,15] that have reported associations between poor depth perception and fractures or falls in the elderly. When evaluating risk by the type of disorder of binocular vision, the strongest association with a risk of musculoskeletal injury, fracture, and fall was in patients with a diagnosis of diplopia. This association is reasonable because double vision implies a lack or reduction of depth perception and the presence of visual confusion, which likely leads to difficulty with visuospatial perception. The disorder of binocular vision with the weakest association was amblyopia. This observation is reasonable because the diagnosis of amblyopia includes a wide range of visual acuities, and therefore many of these beneficiaries have only mild to moderate unilateral vision loss. In addition, amblyopia is a life-long diagnosis; the other disorders of binocular vision, such as diplopia, are more often acute. For this reason, patients with amblyopia may have adapted to their deficit and have less significant disability.

Finding a significant association between disorders of binocular vision and the risk of musculoskeletal injuries, fractures, or falls is consistent with other studies[5,7-9] that have shown vision disorders, such as glaucoma and AMD, increase the risk of fracture or fall. The adjusted OR of musculoskeletal injuries, fractures, or falls with disorders of binocular vision in the present study was 1.27. Using similar analyses, the reported OR for patients with exudative AMD was 1.03 for hip fracture only and for patients with atrophic AMD was 1.11 for hip fracture only; patients with binocular visual field loss associated with glaucoma had a higher OR (1.50 for frequent falls).[9,16] Although these results are similar to those of the present study, they cannot be directly compared given the differences in primary outcome and study methods. However, our findings suggest that disorders of binocular vision contribute to morbidity similar to that associated with other ophthalmic diseases that result in loss of visual acuity or visual field.

Interestingly, we had fewer than expected beneficiaries with cranial nerve palsies. We hypothesize that this may be a result of the study methods, which used claims data and are subject to diagnostic coding preferences of treating physicians. More patients may have had cranial nerve palsies but were coded with other diagnostic codes, such as diplopia, esotropia, exotropia, or hypertropia.

The results of this study of physician administrative claims data must be interpreted within the context of its inherent limitations. First, this study has identified associations, which does not prove causation. Using claims data with diagnostic and procedural coding, we do not know the temporal aspect of the association between a patient's disorder of binocular vision and the reported injury and whether the disorder of binocular vision was diagnosed after the injury. Second, although the study is a large sample of more than 2 million individuals, it is limited to aged beneficiaries enrolled in Medicare fee-for-service benefits with at least 1 year of coverage. Therefore, the results may not be generalizable to other aged populations, other insurance programs, races/ethnicities including Asian and Hispanic, and regions of the world. For example, compared with US census data, we had less representation of Hispanics and Asians.[17] These findings cannot be extrapolated to include the effect of disorders of binocular vision on risk in adults younger than 65 years. In addition, any study using claims data is limited by the completeness of diagnostic and procedural coding and reliable criteria for making specific diagnoses. Although our sample is limited by variable follow-up since we included all patients who had data available for a range of 1 to 10 years, the duration of follow-up was included in our adjusted analysis. In addition, since this study was based on claims codes, a patient with more than 1 diagnosis (eg, fracture and fall) may have only had 1 diagnosis reported. This type of error would bias to an underestimate for the individual secondary outcomes (ie, musculoskeletal injury, fracture, or fall). Finally, we do not know whether the patients used in our data analysis received treatment for their disorder of binocular vision (eg, prisms or surgery) and how this treatment affected our outcome measures.

There is an important advantage to our approach. Our study benefits from the use of the Medicare physician claims database, which is the largest and most comprehensive medical database in the United States and is representative of a large proportion of the population of the United States.

Conclusions

We found that disorders of binocular vision may represent an important risk factor for injuries in adults 65 years or older. Further studies are indicated to determine whether prevention, as well as optical, medical, and surgical interventions, targeting disorders of binocular vision diminishes the risk of musculoskeletal injuries, fractures, and falls in the elderly population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Demographic Characteristics of 2196 881 Eligible Individuals[a]

Characteristic	Patients, No. (%)
Age, y	
65-69	1 081 421 (49.2)
70-74	380 484 (17.3)
75-79	317 033 (14.4)
80-84	225 606 (10.3)
85-89	126 613 (5.8)
≥90	65 724 (3.0)
Sex	
Male	932 207 (42.4)
Female	1 264 674 (57.6)
Race/ethnicity	
White	1 895 012 (86.3)
Black	181 766 (8.3)
Other	120 103 (5.5)
US region of residence	
East	878 870 (40.0)
West	373 539 (17.0)
Midwest	555 107 (25.3)
South	389 365 (17.7)
CCI score	
0	322 428 (14.7)
1-2	545 320 (24.8)
3-4	456 741 (20.8)
≥5	872 392 (39.7)
Other common medical conditions	
Osteoporosis	59 031 (26.9)
Hyperthyroidism	111 877 (5.1)
Hyperparathyroidism	41 703 (1.9)
Glaucoma	489 021 (22.3)
Severe cataract	352 720 (16.1)
Age-related macular degeneration	530 920 (24.2)
Diabetes mellitus with ophthalmic manifestations	178 752 (8.1)
Parkinson disease	81 435 (3.7)
Physically limiting condition	804 237 (36.6)
Any disorder of binocular vision	99 525 (4.5)
Any fracture, musculoskeletal injury, or fall	1 272 948 (57.9)

Characteristic	Patients, No. (%)
Any fracture	1 174 914 (53.5)
Hip fracture	164 227 (7.5)
Any musculoskeletal injury	524 481 (23.9)
Fall	612 217 (27.9)
Duration of Part B coverage during the study period, y	
1	258 633 (11.8)
2	210 569 (9.6)
3	196 635 (9.0)
4	195 255 (8.9)
5	169 512 (7.7)
6	160 535 (7.3)
7	145 999 (6.6)
8	138 468 (6.3)
9	140 546 (6.4)
10	580 729 (26.4)

Abbreviation: CCI score, Charlson Comorbidity Index.

[a]Eligibility criteria included age 65 years or older with at least 1 year of Medicare Part B enrollment during 2002-2011.

Table 2
Diagnoses Reported for Patients With Disorders of Binocular Vision

ICD-9-CM Code[a]	Brief Descriptor	No. (%)[b]
378.X	Strabismus	51 234 (2.3)
378.0X;	Esotropia	11 135 (0.5)
378.1X	Exotropia	11 627 (0.5)
368.0X	Amblyopia	19 109 (0.9)
368.2	Diplopia	47 309 (2.2)
368.3X	Other disorders of binocular vision	1810 (0.1)
379.5X	Nystagmus	4056 (0.2)
951.0	Oculomotor nerve palsy	60 (0)
951.1	Trochlear nerve palsy	72 (0)
951.3	Abducens nerve palsy	62 (0)

Abbreviation: *ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification*.

[a]The *ICD-9-CM* codes are truncated where the fourth digit is used to provide broad categories for these analyses; X is a placeholder.

[b]The denominator used was the entire cohort.

Table 3

Comparison of Demographic Characteristics Between Beneficiaries With and Without DisordersofBinocular Vision[a]

Characteristic	Disorder of Binocular Vision, No. (%)[b]	
	Patients Without	Patients With
Age, y		
65-69	1 041 098 (49.6)	40 323 (40.5)
70-74	358 561 (17.1)	21 923 (22.0)
75-79	297 983 (14.2)	19 050 (19.1)
80-84	213 749 (10.2)	11 857 (11.9)
85-89	121 620 (5.8)	4993 (5.0)
≥90	64 345 (3.1)	1379 (1.4)
Sex		
Male	888 300 (42.4)	43 907 (44.1)
Female	1 209 056 (57.6)	55 618 (55.9)
Race		
White	1 803 589 (86.0)	91423 (91.9)
Black	177 340 (8.4)	4426 (4.4)
Other	116 427 (5.6)	3676 (3.7)
US region of residence		
East	838 083 (40.0)	40 787 (41.0)
West	357 017 (17.0)	16 522 (16.6)
Midwest	527 782 (25.2)	27 325 (27.5)
South	374 474 (17.8)	14 891 (15.0)
CCI score		
0	315 905 (15.1)	6523 (6.6)
1-2	526 635 (25.1)	18 685 (18.8)
3-4	435 399 (20.8)	21 342 (21.4)
≥5	819 417 (39.1)	52 975 (53.2)

Abbreviation: CCI, Charlson Comorbidity Index.

[a] All differences were significant at $P < .001$ by the χ^2 test.

[b] The cohort included a 5% Medicare sample from 2002 to 2011.

Table 4

Ten-Year Prevalence of Fractures, Falls, orMusculoskeletal Injuries Among Beneficiaries With Disorders of Binocular Vision[a]

Characteristic (No.)	No. (%) With Injury[b]		OR (95% CI)	
	With Disorder of Binocular Vision	Without Disorder of Binocular Vision	Unadjusted[c]	Adjusted[c]
Fracture				
Any (1 174 914)	69 964 (70.3)	1 104950 (52.7)	2.13 (2.10-2.15)	1.24 (1.23-1.26)
Hip (164 227)	10 311 (10.4)	153 916 (7.3)	1.46 (1.43-1.49)	1.04 (1.02-1.07)
Fall (612 217)	40 058 (40.2)	572159 (27.3)	1.80 (1.77-1.82)	1.20 (1.18-1.21)
Musculoskeletal injury (524 481)	35 515 (35.7)	488 966 (23.3)	1.83 (1.80-1.85)	1.23 (1.21-1.25)
Musculoskeletal injury, fracture, or fall (1 272 948)	74 504 (74.9)	1 198 444 (57.1)	2.23 (2.20-2.27)	1.27 (1.25-1.29)

Abbreviation: OR, odds ratio.

[a] Multivariable logistic regression model was adjusted for age, sex, race, US region of residence, Charlson Comorbidity Index score, osteoporosis, hyperthyroidism, hyperparathyroidism, glaucoma, severe cataract, age-related macular degeneration, diabetes mellitus with ophthalmic manifestations, Parkinson disease, physically limiting conditions, and duration of Medicare Part B coverage. The cohort included a 5% Medicare sample from 2002 to 2011. Each person was included in the global analysis one time.

[b] The denominators are the total number of each cohort: with a disorder of binocular vision, 99 525; and without a disorder of binocular vision, 2 097 356.

[c] All differences were significant at $P < .001$.

Table 5

Ten-Year Prevalence of Fractures, Falls, and Musculoskeletal Injuries Among Beneficiaries According to Disordersof Binocular Vision[a]

Disorder of Binocular Vision (*ICD-9-CM* Code)	No. of Patients With Diagnosisand Fractures, Falls, or MusculoskeletalInjuries	OR (95% CI)			
		Adjusted[b]	*P* Value	Adjusted[c]	*P* Value
Strabismus (378. XX)	38 596	1.28 (1.26-1.31)	<.001	1.17 (1.15-1.20)	<.001
Esotropia (378.0X)	8489	1.30 (1.24-1.37)	<.001		
Exotropia (378.1X)	8646	1.27 (1.21-1.33)	<.001		
Other strabismus (378.5X)	10 525	1.24 (1.19-1.29)	<.001		
Amblyopia (368.0X)	13 366	1.12 (1.08-1.16)	<.001	1.08 (1.04-1.12)	<.001
Diplopia (368.2)	36 781	1.36 (1.33-1.39)	<.001	1.27 (1.24-1.31)	<.001
Disorders of binocular vision (368.3X)	1389	1.27 (1.13-1.43)	<.001	1.14 (1.01-1.28)	.04
Nystagmus (379.5X)	3080	1.32 (1.22-1.43)	<.001	1.23 (1.14-1.33)	<.001

Abbreviations: *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification*; OR, odds ratio.

[a] The cohort included a 5% Medicare sample from 2002 to 2011.

[b] Compared each subtype of disorder of binocular vision with the sample without a disorder of binocular vision individually after adjusting for age, sex, race, US region of residence, Charlson Comorbidity Index score, osteoporosis, hyperthyroidism, hyperparathyroidism, glaucoma, severe cataract, age-related macular degeneration, diabetes mellitus with ophthalmic manifestations, Parkinson disease, physically limiting conditions, and duration of Medicare Part B coverage in a multivariable logistic regression model.

[c] Compared specific subtypes of disorders of binocular vision with the sample without a disorder of binocular vision simultaneously after adjusting for age, sex, race, US region of residence, Charlson Comorbidity Index score, osteoporosis, hyperthyroidism, hyperparathyroidism, glaucoma, severe cataract, and age-related macular degeneration.