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# Characteristics of Falls among Community-Dwelling Older Adults: The SCOPE Study

Itshak Melzer[a] Ellen Freiberger[b] Sabine Britting[b] Fabrizia Lattanzio[c] Yehudit Melzer[a, d] Ronit Ben-Romano[a] Regina Roller-Wirnsberger[e] Gerhard Wirnsberger[f] Francesco Mattace-Raso[g] Lisanne Tap[g] Pedro Gil[h] Francesc Formiga[i] Rafael Moreno-González[i] Tomasz Kostka[j] Agnieszka Guligowska[j] Johan Arnlov[k, l, m] Axel C. Carlsson[k, l, m] Paolo Fabbietti[c] Robert Kob[b] on behalf of the SCOPE investigators

[a]Department of Physical Therapy, Recanati School for Community Health Professions at the Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel; [b]Department of Internal Medicine-Geriatrics, Institute for Biomedicine of Aging (IBA), Friedrich-Alexander-Universität Erlangen-Nürnberg, Nuremberg, Germany; [c]Italian National Research Center on Aging (IRCCS INRCA), Ancona, Italy; [d]Maccabi Health Organization, Tel Aviv, Israel; [e]Department of Internal Medicine, Medical University of Graz, Graz, Austria; [f]Division of Nephrology, Department of Internal Medicine, Medical University of Graz, Graz, Austria; [g]Department of Internal Medicine, Section of Geriatric Medicine, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands; [h]Faculty of Medicine, Département of Medicine Pza, Ciudad Universitaria, Madrid, Spain; [i]Geriatric Unit, Internal Medicine Department, Bellvitge University Hospital – IDIBELL, L'Hospitalet de Llobregat, Barcelona, Spain; [j]Department of Geriatrics, Healthy Ageing Research Centre, Medical University of Lodz, Lodz, Poland; [k]Department of Medical Sciences, Uppsala University, Uppsala, Sweden; [l]School of Health and Social Studies, Dalarna University, Falun, Sweden; [m]Division of Family Medicine, Department of Neurobiology, Care Sciences and Society, Karolinska Institutet, Huddinge, Sweden

**Keywords**
Fall · Injurious falls · Community-dwelling old adults

**Abstract**
***Introduction:*** Falls among older adults are frequent and will remain a health concern. We describe fall characteristics among older adults living independently in the community based on location, severity, and sex. ***Methods:*** As part of the SCOPE study, fall occurrence, location, causes, circumstances, and consequences were reported by 1,754 community-dwelling older adults across Europe at baseline (F0), 12-month follow-up (FU12), and 24-month follow-up (FU24). A geriatric assessment that included demographics, clinical and medication assessment, depression, Cumulative Illness Rating Scale, blood and urine examination, hand grip strength, and fear of falling was performed. Falls characteristics were described, and a multivariate logistic regression analysis was performed to examine the probability of being severely injured because

karger@karger.com
www.karger.com/ger



Correspondence to:
Itshak Melzer, itzikm@bgu.ac.il
Paolo Fabbietti, p.fabbietti@inrca.it

of a fall, inside or outdoors. ***Results:*** Data on falls revealed 938 falls at baseline, 773 falls at FU12, and 797 falls at FU24. Approximately 70% of these falls resulted in no injury or untreated injuries, while 8.5% led to bone fractures. Most falls (54.8%) occurred outdoors, primarily during ambulation (64.6%). About 50% of the falls were due to trips, slips, or bumping into objects, while 20.3% were due to balance and gait impairments. Women experienced falls about 30% more frequently than men. ***Conclusions:*** Our findings offer new insights into the patterns of falls by location, sex, and injury type. This may help suggest ways of preventing falls. It is reasonable to recommend that older adults train their balance and specifically balance reactive responses to a situation whenever balance is lost accidently and unexpectedly.


## Introduction

Falls represent a significant threat to the health and well-being of older adults. Falls are the sixth leading cause of death among individuals aged 65 and above [1]. In 2021, the World Health Organization estimated that each year, about 684,000 individuals die from falls globally and that 37.3 million falls are severe enough to require medical attention [2]. Most unintentional injuries among older adults are primarily resulting from falls, causing serious injury 20–30% of the time [3, 4] and 2–5% of falls lead to hospital visits [5]. The most severe injuries are fractures [5] and traumatic brain injuries [2]. Falls also result in increased fear of falling [6] and dependence [7]. In the first year following a hip fracture, 25% of older patients will die [5]. Older adults' falls lead to USD 50 billion in medical costs annually in the USA [8], and EUR 25 billion in the European Union [9].

While considerable attention has been directed toward identifying underlying risk factors and mechanisms for falls, there is less research that has investigated the specific locations and activities engaged in by community-dwelling older adults at the time of a fall and their relation to injurious falls. Past studies indicate that older adults are more prone to experiencing falls and subsequent injuries indoors rather than outdoors [10–16]. Older adults face a higher risk of injury or fatality from falls inside their homes [14, 15] compared to those occurring outdoors [17]. As individuals age, both the occurrence of indoor falls and subsequent visits to emergency departments increase [12]. Studies examining disparities in fall locations and injuries yield inconclusive results [10–16]. This may be the case since studies examining community falls relied on self-reported or witness accounts of fall incidents, which could be prone to inaccuracies [11–15, 18–21]. Other studies focused on electronic medical records from emergency department visits of people aged 65 years and older who had experienced unintentional falls as the primary cause of injury, which may not represent the circumstances and causes of less severe injurious, untreated or non-injurious falls [10, 16, 19–21]. Another way to investigate falls is by studies that utilize video-cameras that capture fall events in public areas [22–27]. Although these observations are practical, they are limited because they were made in an environment that is controlled by the retirement or nursing home management, in corridors and public areas. Since these studies were conducted among older adults residing in long-term care settings, the findings may not be generalizable to older adults living independently in the community.

Notably, there is a need for more data concerning the contextual differences in the consequences of falls between community-dwelling older adults who fell inside their home vs. outside home. In addition, exploring the activities performed during a fall, and causes of injurious falls and non-injurious falls are needed. This distinction holds significance as it has been advocated that severely injured older adults should be prioritized for diagnostic and preventive interventions [10–21, 28, 29]. Also, these older adults may exhibit a higher prevalence of underlying medical neurological and musculoskeletal conditions, predisposing them to further falls [30]. Consequently, we aimed to describe: (1) fall characteristics (cause, activity, location, consequences) among older adults living independently in the community; (2) the characteristics of falls based on their location (i.e., inside home and outdoors); (3) the characteristics of falls that resulted in severe injury, i.e., bone fracture vs. non-severe injury; (4) the difference in fall characteristics between sexes. Such insights regarding cause, situation, locations, consequences, and related injuries are pivotal for comprehending the etiology of falls and for formulating efficacious clinical assessments and preventive interventions.

## Methods

*Study Population*

The study, "Screening for Chronic Kidney Disease (CKD) among Older People across Europe" (SCOPE) (European grant agreement number 436849), is a

multicenter 2-year prospective cohort study involving 2,461 older adults, aged 75 years old and above, living independently in the community in participating institutions in Austria, Germany, Israel, Italy, the Netherlands, Poland, and Spain. Methods of the SCOPE study have been described in detail [31]. Participants were excluded if they were patients with End Stage Renal Disease or dialysis, history of solid organ or bone marrow transplantation, active malignancy within 24 months prior to screening or metastatic cancer, life expectancy of less than 6 months, severe cognitive impairment (MMSE <10), and patients unwilling to provide consent and those who cannot be followed-up. The study protocol was approved by Ethics Committees at all participating institutions and complies with the Declaration of Helsinki and Good Clinical Practice Guidelines. Participants signed a written informed consent before entering the study.

*Study Protocol*

Participants were invited to visit our study center where we accessed their self-reported medical records and conducted tests that included demographics, clinical physical assessment, number of diseases including osteoporosis and medications taken, family arrangements; Basic and Instrumental Activities of Daily Living; 15-items Geriatric Depression Scale (GDS); Cumulative Illness Rating Scale (CIRS/overall comorbidity); Lower urinary tract symptoms (LUTS); Euro-Quality of life 5D-VAS; hand grip strength and number of medications taken. Blood and urine samples were also collected. The estimated glomerular filtration rate (eGFR) was calculated by the Berlin Initiative Study (BIS) equation, which is standard in clinical practice guidelines for chronic kidney disease (K/DOQI clinical practice guidelines).

In addition, characteristics of falls and circumstances were collected at baseline (F0), 12-month follow-up (FU12), and 24-month follow-up (FU24). In this work, the definition of fall is consistent with previous research: "the consequence of movement unintentionally and unexpectedly to the ground from a higher position" [3]. The participants interviewed and reported the circumstances and consequences of each fall, including: How many times have you fallen in the past 12 months? The location of fall: (i) inside the home, (ii) outside home but inside a building, (iii) outdoors. What were you doing at the time of fall? — (i) ambulation (walking, turning, standing), (ii) transferring (getting in/out of the bed, chair or car, getting on/off toilet, climbing stool, chair, or ladder), (iii) running, (iv) sports activity, (v) stair climbing or curb descending. Participants were also asked what caused the fall? — (i) accidental falls due to trips, slips, bumping into object, (ii) collapse episode, (iii) dizziness/vertigo, (iv) balance/gait impairment (quick movement, self-induced balance loss). In case of a fall, we retrieved from medical records what kind of injuries they sustained from a fall? — (i) bone fractures, (ii) treated injury, (iii) untreated injury, (iv) no injury. The extent of fear of falling was measured with a single question with possible answers ranging from not at all concerned, somewhat concerned, fairly concerned and very concerned.

*Data and Statistical Analysis*

Descriptive statistics (mean, standard deviation, and percentages) was used to characterize the cohort. As some of the data were not normally distributed, non-parametric Wilcoxon rank-sum tests and chi-squared tests were used to assess the differences in fall characteristics between older adults who fell at home, outside, and outside home but inside a building. In addition, we assessed differences between the severity of the injurious falls as well as differences between women and men.

First, the overall/total fall events follow the baseline measure (F0) and the next 2 years of monitoring period in FU12 and in FU24 (see flowchart Fig. 1). Percentage for selected circumstances, location, and consequences of falls during F0, FU12, and FU24 were examined from all falls. Second, we divided the falls based on location of fall to (1) fall inside the home; (2) fall outdoors but inside a building; and (3) fall outdoors. Falls data were divided by location of the fall event, for example, in case a participant fell inside home in F0, outdoors in FU12, then outdoors but inside a building in FU24, his/her data records results were divided by the location fall. Third, we categorized all 2,508 falls based on their consequences during F0, FU12, and FU24 as follows: (1) severe injury; (2) treated injury; (3) untreated injury; and (4) no injury. Fall data were categorized based on the injury consequences resulting from each fall. For instance, if a participant experienced a severe injury (e.g., bone fracture) in F0, an untreated injury in FU12, and no injury in FU24, their data record was divided accordingly, reflecting the outcome of each individual fall. Fourth, we compared the selected circumstances and consequences of all falls between sexes during the study periods F0, FU12, and FU24. It is possible that both men and women experienced falls in each follow-up period, and each of their falls was described based on the specific circumstances and outcomes of that incident.

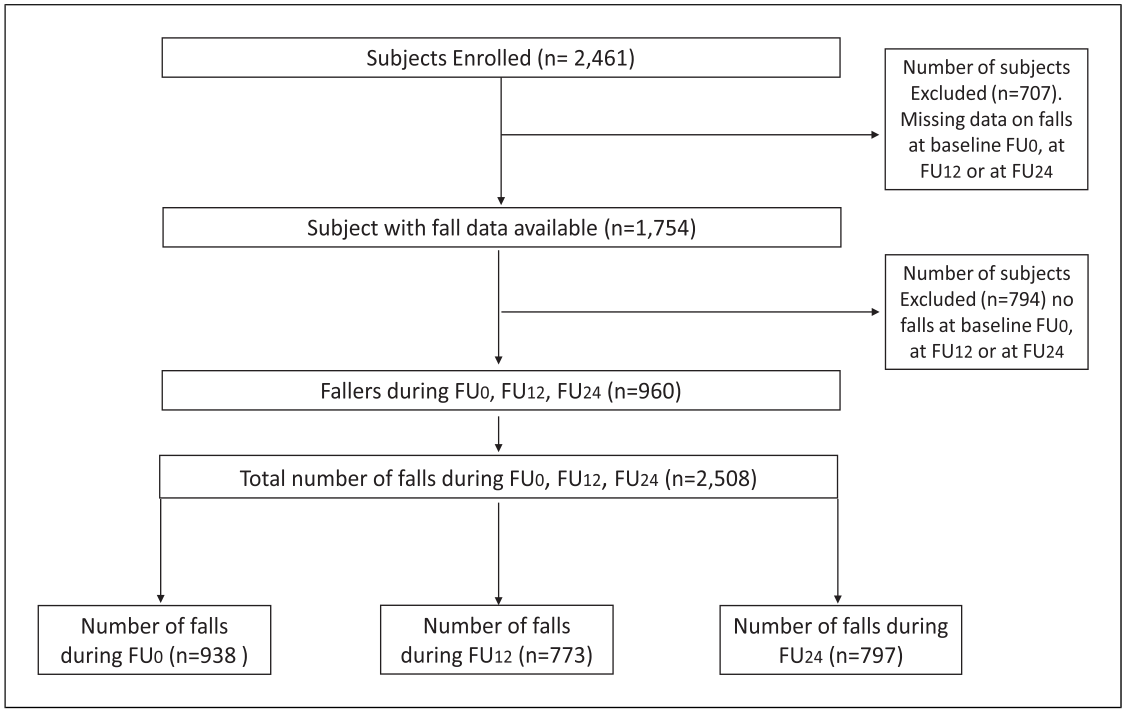



**Fig. 1.** Study flowchart.

Finally, multivariable logistic regression analyses were performed examining the probability of having been severely injured because of a fall, i.e., bone fracture in older adults who fell inside their homes and older adults who fell outside their homes. We adjusted the first logistic regression model for age and sex, then the model was adjusted for stroke; hypertension; anemia; mood status, i.e., GDS >5; CIRS; number of medications≥5; and hand grip strength. Statistical significance was set a priori at $p < 0.05$. All analyses were performed with SPSS v.24 (SPSS Inc., Chicago, IL, USA).

## Results

Of the 2,461 older adults initially enrolled in the study, 707 were excluded due to missing data on falls at baseline (F0), FU12, and FU24. Additionally, 794 older adults were excluded because they reported no falls at any of these time points. Consequently, 960 older adults who reported at least one fall during F0, FU12, or FU24 were analyzed. These individuals reported 349 falls at baseline, 314 at FU12, and 324 at FU24, totaling 987 falls from older adults who fell once. An additional 1,521 falls were reported by older adults who experienced multiple falls during the study: 589 at baseline, 459 at FU12, and 473 at FU24. Thus, a total of 2,508 falls were analyzed in this study (flowchart; Fig. 1).

*Circumstances of Falls*

Findings regarding the circumstances of falls are presented in Figure 2. Due to missing data, the available cases are location of falls ($n$ = 2,067), activity during falls ($n$ = 2,065), causes of falls ($n$ = 2,064), and consequences of falls ($n$ = 2,058). Figure 2a shows that falls were more likely to occur outdoors rather than at home (54.8% and 37.7%, respectively); 7.5% occurred outside home but inside a building. Figure 2b provides a summary of the findings, highlighting the activities in which individuals were engaged at the time of a fall. Ambulation, specifically walking, was ranked as the most frequent activity (64.6%), and transferring was the 2nd most common activity accounted for a fall (15.2%). Fallers were also requested to select all applicable choices from a list of 5 reasons of what caused the fall. The most frequently cited reasons are summarized in Figure 2c. Fifty percent of falls were accidental falls, such as trips, slips, or bumping into object attributed to environmental reasons, and 28.3% of falls were attributed to balance and gait impairment. As illustrated in Figures 2d, 42.1% of falls resulted in no injury, and bone fractures occurred in 8.5% of falls during the study period ($n$ = 174).

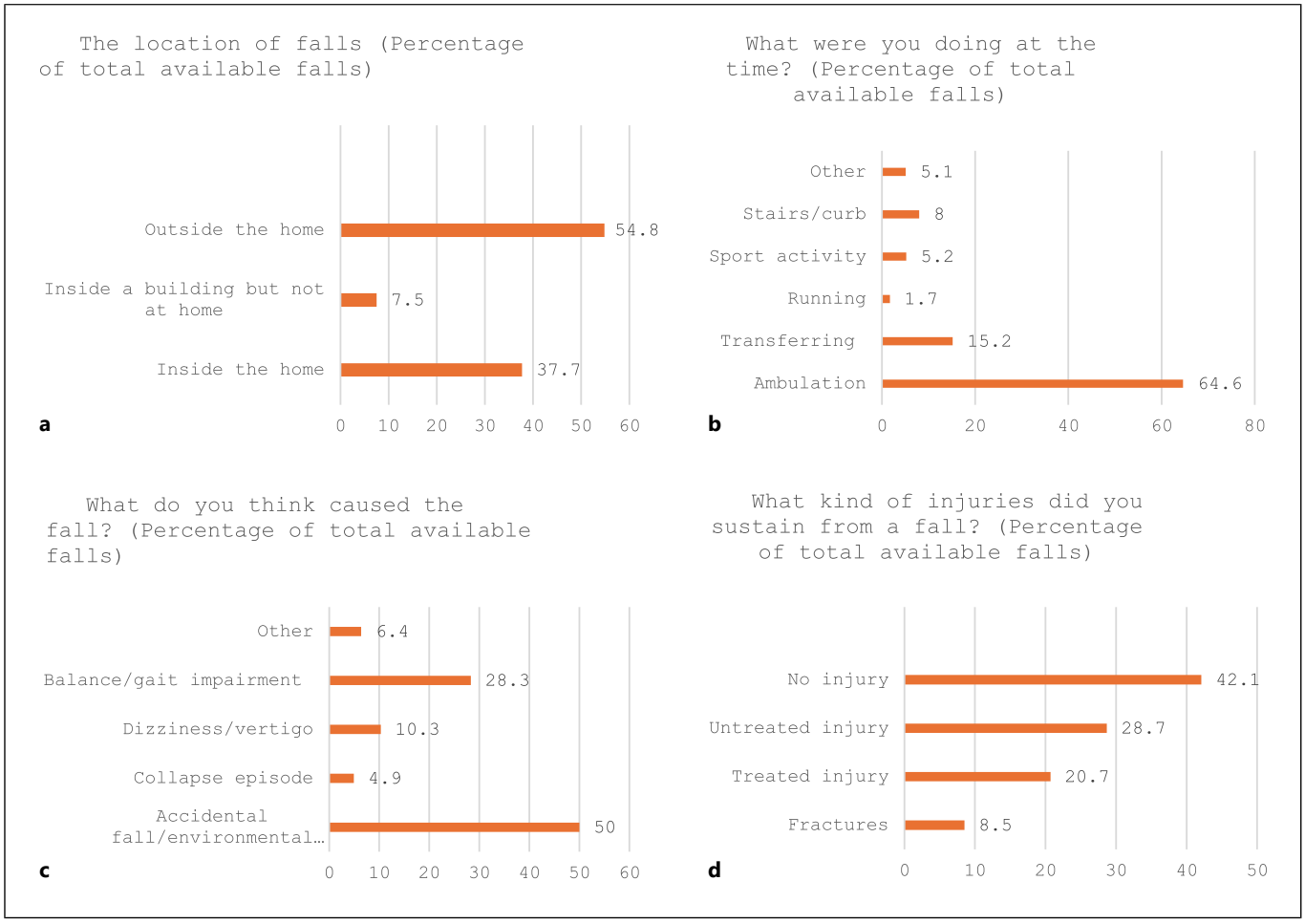
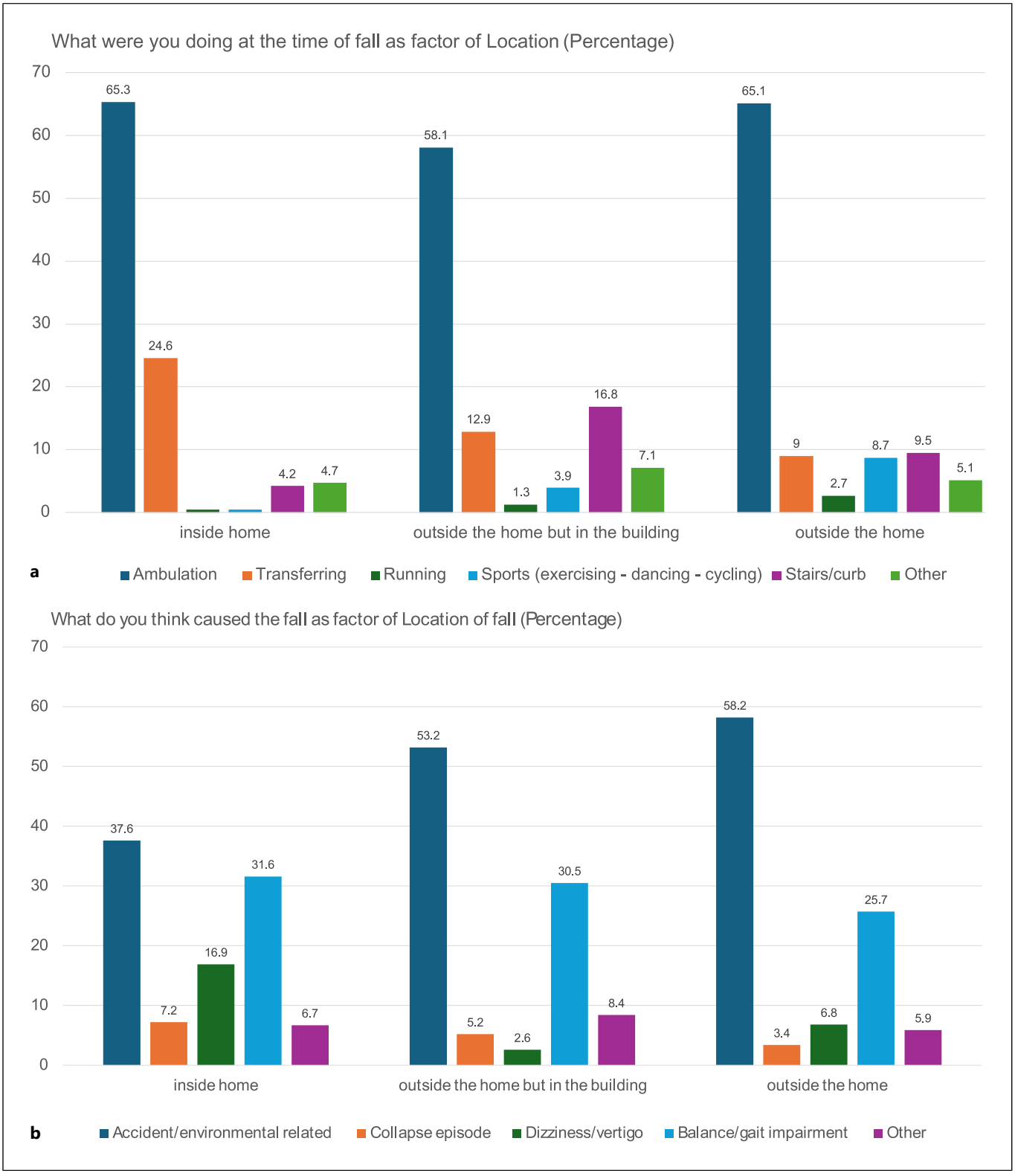



**Fig. 2.** Circumstances of falls presented as the percentage of self-reported cases for location of fall ($N$ = 2,067) (**a**), activity during fall ($N$ = 2,065) (**b**), causes of fall ($N$ = 2,064) (**c**), and consequences of fall ($N$ = 2,058) (**d**).

*Location of Falls*

Out of the total, 2,508 falls, 780 occurred inside the home, 1,132 took place outdoors, 155 happened outside the home but inside a building, there was missing data on the location of falls in 441 falls (Fig. 3). Descriptive statistics used to characterize the cohort based on the location of falls are presented in Table 1. Compared to older adults that fell outdoors, "home fallers" were significantly older (80 vs. 79), more likely females (66.0% vs. 61.3%) and more likely to suffer from hypertension (81.3% vs. 77.4%), anemia (25.2% vs. 16.6%), depression (22.1% vs. 16.8%), and cognitive impairments (12.2% vs. 5.8%). Outdoor falls were significantly associated with higher hand grip strength compared to inside fall (24 kg vs. 22 kg), lower probability of having a history of stroke (5.4% vs. 10.3%) and higher eGFR (56.1 mL/min/1.73 $m^2$ vs. 54.6 mL/min/1.73 $m^2$) than falls at home. The percentage of persons taking at least 5 current medications significantly increases from outdoor falls (66.8%) over falls that occurred outside home but inside a building (72.9%) to home falls (76.9%).

The activities and causes of falls at home and outdoors that were determined from participants' descriptions of their falls are presented in Figure 3. Figure 3a shows that ambulation was ranked as the most frequent activity, accounted for loss of balance and a fall inside the home and transferring as the second most common activity (65.3% and 24.6%, respectively). Ambulation was also ranked as the most common activity, accounting for falls outside the home but inside a building (58.1%), and outdoor (65.1%). Stair climbing, or curb descending, however, was the second most common activity during a fall outside home but inside a building, and outdoors (16.8% and 9.5%, respectively). Fallers were also requested to select all applicable choices from a list of 5 reasons for what caused the

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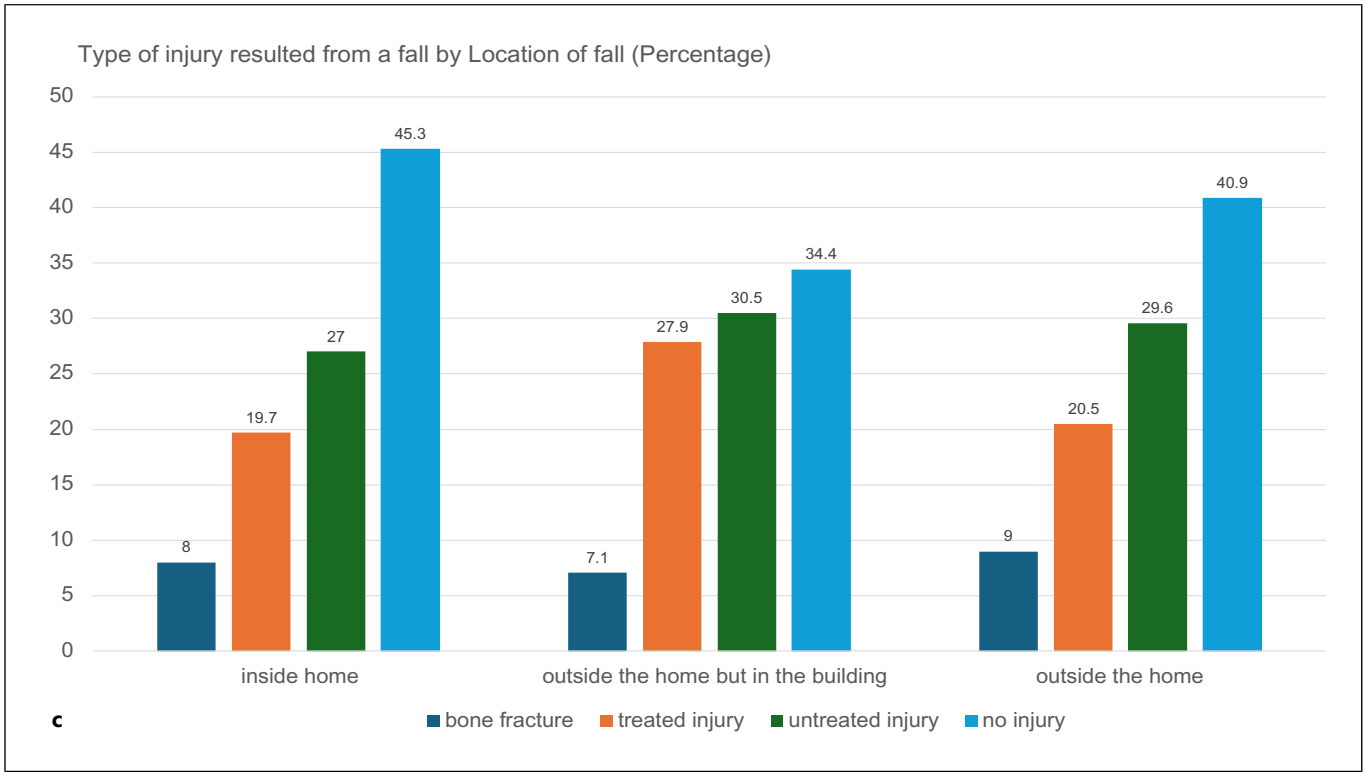



**Fig. 3.** Location of fall ($N$ = 2,065), categorized as inside the home ($n$ = 779), outside the home but within the building ($n$ = 155), and outside the home ($n$ = 1,131), presented as the percentage of self-reported cases for activities (**a**), causes (**b**), and consequences of falls (**c**), across these locations.

fall. The most frequently cited reasons are summarized in Figure 3b, showing that 37.5% of falls inside the home were attributed to environmental reasons such as slips or trips; this percentage grew in falls outside the home but inside a building (53.2%) and was even higher outdoors (58.2%). The second leading cause of fall in all locations was attributed to balance/gait impairments (31.6%, 30.5%, and 25.7%, respectively). Interestingly, dizziness caused a large amount of falls inside the home (16.9%) compared to falls outside the home but inside a building (2.9%) and outdoors (6.8%). As illustrated in Figure 3c, severe injurious falls (bone fractures) were similar across all locations: 8.0% of falls inside the home, 7.1% of falls outside the home but inside a building, and 9.0% outdoors.

*Consequences of Falls*

Of the total 2,508 falls, 174 resulted in bone fractures, 427 required treatment for injury, 591 caused untreated injury, and 866 were non-injurious. This accounts for 2,058 falls with recorded outcomes, excluding 450 falls with missing data on their consequences. We compared the activities and causes of severe injurious falls versus less severe or non-injurious falls (Table 2). Participants who sustained a bone fracture as a result of a fall were mostly women (72.4%) and reported significantly more hip fractures and more osteoporosis (23%, and 51.1%) compared to those experiencing a less severe injurious fall.

Figure 4a shows that ambulation was ranked as the most common activity, accounted for bone fracture (69.5%) and slightly higher than other types of injurious and non-injurious falls (60.4% and 66.1%). Transferring was the second most common activity and accounted for bone fracture (13.2%), somewhat lower than injurious and non-injurious falls (14.7% and 16.4%). Injurious falls were mainly caused by environmental reasons such as slips or trips, with the highest percentage (56.3%) resulting in a severe injury (i.e., bone fracture). The second most common cause of a bone fracture was related to balance and gait impairments (26.4%). This was similar to less severe injurious and non-injurious falls (23.3% and 30.2%). Figure 4c shows that falls outdoor were ranked as the most frequent location for severe injurious falls (58%); this was somewhat higher than other types of injurious and non-injurious falls (53.2% and 56.5%).

**Table 1.** Sociodemographic characteristics, clinical, laboratory parameters, and physical, cognitive and emotional status, according to location of fall ($n$ = 2,067)

| Variable | Group A: fall inside home ($n$ = 780) | Group B: fall outside home but inside a building ($n$ = 155) | Group C: fall outside home ($n$ = 1,132) | $p$ value | Post hoc |
|---|---|---|---|---|---|
| Age, years | 80 (7) | 79 (5) | 79 (6) | <0.001 | A vs. B<br>A vs. C |
| Sex: female, $n$ (%) | 515 (66.0) | 95 (61.3) | 681 (60.2) | 0.032 | A vs. B<br>A vs. C |
| BMI, kg/m$^2$ | 27.8 (6.1) | 27.9 (4.6) | 27.5 (5.2) | 0.697 | |
| Marital status, $n$ (%) | | | | 0.006 | A vs. B<br>B vs. C |
| Single | 51 (6.5) | 20 (12.9) | 88 (7.8) | | |
| Married/living with a partner | 369 (47.3) | 69 (44.5) | 570 (50.4) | | |
| Separated/divorced | 58 (7.4) | 4 (2.6) | 93 (8.2) | | |
| Widowed | 302 (38.7) | 62 (40.0) | 381 (33.7) | | |
| Diabetes, $n$ (%) | 215 (27.6) | 43 (27.7) | 260 (23.0) | 0.054 | |
| Hypertension, $n$ (%) | 634 (81.3) | 120 (77.4) | 849 (75.0) | 0.005 | A vs. B<br>A vs. C |
| Stroke, $n$ (%) | 71 (9.1) | 16 (10.3) | 61 (5.4) | 0.002 | A vs. C<br>B vs. C |
| Hip fractures, $n$ (%) | 56 (7.2) | 13 (8.4) | 65 (5.7) | 0.276 | |
| COPD, $n$ (%) | 117 (15.0) | 21 (13.5) | 137 (12.1) | 0.185 | |
| Osteoporosis, $n$ (%) | 257 (32.9) | 45 (29.0) | 365 (32.2) | 0.635 | |
| Parkinson's disease, $n$ (%) | 22 (2.8) | 1 (0.6) | 21 (1.9) | 0.147 | |
| Anemia, $n$ (%) | 185 (25.2) | 24 (16.6) | 184 (17.1) | <0.001 | A vs. B<br>A vs. C |
| CIRS | 10 (7) | 9 (7) | 8 (7) | <0.001 | A vs. C |
| Take ≥5 current medications, $n$ (%) | 600 (76.9) | 113 (72.9) | 756 (66.8) | <0.001 | A vs. B<br>A vs. C<br>B vs. C |
| LUTS moderate or big problems, $n$ (%) | 305 (39.1) | 56 (36.1) | 398 (35.2) | 0.211 | |
| eGFR (BIS equation), mL/min/1.73 m$^2$ | 53.8 (22.1) | 54.6 (22.6) | 56.1 (18.9) | 0.005 | A vs. C<br>B vs. C |
| Hemoglobin, mg/dL | 13.3 (1.9) | 13.5 (1.9) | 13.5 (1.8) | <0.001 | A vs. B<br>A vs. C |
| Hand grip strength, kg | 21 (12) | 22 (12) | 24 (12) | <0.001 | A vs. C<br>B vs. C |
| GDS >5, $n$ (%) | 172 (22.1) | 26 (16.8) | 147 (13.0) | <0.001 | A vs. B<br>A vs. C |
| MMSE <24, $n$ (%) | 95 (12.2) | 9 (5.8) | 60 (5.3) | <0.001 | A vs. B<br>A vs. C |

Data about falls during the whole study period (baseline, FU12, and FU24). Values are $n$ (%) for categorical variables, and median (interquartile range) for continuous. NS, not significance; ADL, activities of daily living; BMI, body mass index; CIRS, Cumulative Illness Rating Score; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; GDS, Geriatric Depression Scale; iADL, instrumental activities of daily living; LUTS, lower urinary tract symptoms; MMSE, Mini-Mental State Examination.

**Table 2.** Sociodemographic characteristics, clinical, laboratory parameters, and physical, cognitive and emotional status, according to kind of injuries fall ($n$ = 2,058)

| Variable | Group A: bone fracture ($n$ = 174) | Group B: treated injury ($n$ = 427) | Group C: untreated injury ($n$ = 591) | Group D: no injury ($n$ = 866) | $p$ value | Post hoc |
|---|---|---|---|---|---|---|
| Age, years | 79.5 (7) | 79 (6) | 79 (5) | 80 (7) | 0.019 | B vs. D<br>C vs. D |
| Sex: female, $n$ (%) | 126 (72.4) | 294 (68.9) | 386 (65.3) | 482 (55.7) | <0.001 | A vs. C<br>A vs. D<br>B vs. D |
| BMI, kg/m$^2$ | 27.3 (5.8) | 27.7 (6.0) | 27.8 (5.5) | 27.4 (5.7) | 0.555 | |
| Marital status, $n$ (%) | | | | | <0.001 | A vs. B<br>A vs. C<br>A vs. D<br>C vs. D |
| Single | 13 (7.5) | 30 (7.0) | 33 (5.6) | 83 (9.6) | | |
| Married/living with a partner | 70 (40.2) | 213 (49.9) | 266 (45.0) | 451 (52.1) | | |
| Separated/divorced | 15 (8.6) | 37 (8.7) | 58 (9.8) | 45 (5.2) | | |
| Widowed | 76 (43.7) | 147 (34.4) | 234 (39.6) | 287 (33.1) | | |
| Education, years | 11 (7) | 12 (6) | 11 (6) | 11 (6) | 0.012 | A vs. B<br>B vs. C<br>B vs. D |
| Diabetes, $n$ (%) | 38 (21.8) | 110 (25.8) | 147 (24.9) | 222 (25.6) | 0.746 | |
| Hypertension, $n$ (%) | 129 (74.1) | 337 (78.9) | 458 (77.5) | 671 (77.5) | 0.654 | |
| Stroke, $n$ (%) | 12 (6.9) | 38 (8.9) | 44 (7.4) | 50 (5.8) | 0.208 | |
| Hip fractures, $n$ (%) | 40 (23.0) | 26 (6.1) | 21 (3.6) | 47 (5.4) | <0.001 | A vs. B<br>A vs. C<br>A vs. D |
| COPD, $n$ (%) | 22 (12.6) | 54 (12.6) | 86 (14.6) | 111 (12.8) | 0.753 | |
| Osteoporosis, $n$ (%) | 89 (51.1) | 146 (34.2) | 168 (28.4) | 260 (30.0) | <0.001 | A vs. B<br>A vs. C<br>A vs. D |
| Parkinson's disease, $n$ (%) | 4 (2.3) | 12 (2.8) | 6 (1.0) | 22 (2.5) | 0.159 | |
| Anemia, $n$ (%) | 37 (22.2) | 66 (16.1) | 104 (18.5) | 185 (22.9) | 0.025 | A vs. B<br>A vs. C<br>B vs. D<br>C vs. D |
| CIRS | 7 (6.5) | 9 (7) | 9 (7) | 9 (7) | 0.002 | A vs. B<br>A vs. C<br>A vs. D |
| Take ≥5 current medications, $n$ (%) | 125 (71.8) | 302 (70.7) | 415 (70.2) | 619 (71.5) | 0.951 | |
| LUTS moderate or big problems, $n$ (%) | 58 (33.3) | 184 (43.1) | 225 (38.1) | 286 (33.0) | 0.003 | A vs. B<br>A vs. C<br>B vs. D<br>C vs. D |
| eGFR (BIS equation), mL/min/1.73 m$^2$ | 59.2 (20.4) | 54.0 (19.2) | 54.8 (20.1) | 55.0 (20.9) | 0.004 | A vs. B<br>A vs. C<br>A vs. D |

**Table 2** (continued)

| Variable | Group A: bone fracture ($n$ = 174) | Group B: treated injury ($n$ = 427) | Group C: untreated injury ($n$ = 591) | Group D: no injury ($n$ = 866) | $p$ value | Post hoc |
|---|---|---|---|---|---|---|
| Hemoglobin, mg/dL | 13.3 (1.8) | 13.5 (1.8) | 13.5 (1.9) | 13.4 (1.8) | 0.549 | |
| Hand grip strength, kg | 21.5 (10) | 22 (11) | 22 (11) | 24 (12) | 0.069 | |
| GDS >5, $n$ (%) | 39 (22.4) | 62 (14.5) | 107 (18.1) | 134 (15.5) | 0.062 | |
| MMSE <24, $n$ (%) | 16 (9.2) | 25 (5.9) | 51 (8.6) | 72 (8.3) | 0.327 | |

Data about falls during the whole study period (baseline, FU12, and FU24). Values are $n$ (%) for categorical variables, and median (interquartile range) for continuous. NS, not significance; ADL, activities of daily living; BMI, body mass index; CIRS, Cumulative Illness Rating Score; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; GDS, Geriatric Depression Scale; iADL, instrumental activities of daily living; LUTS, lower urinary tract symptoms; MMSE, Mini-Mental State Examination.

*Comparisons between Sexes*

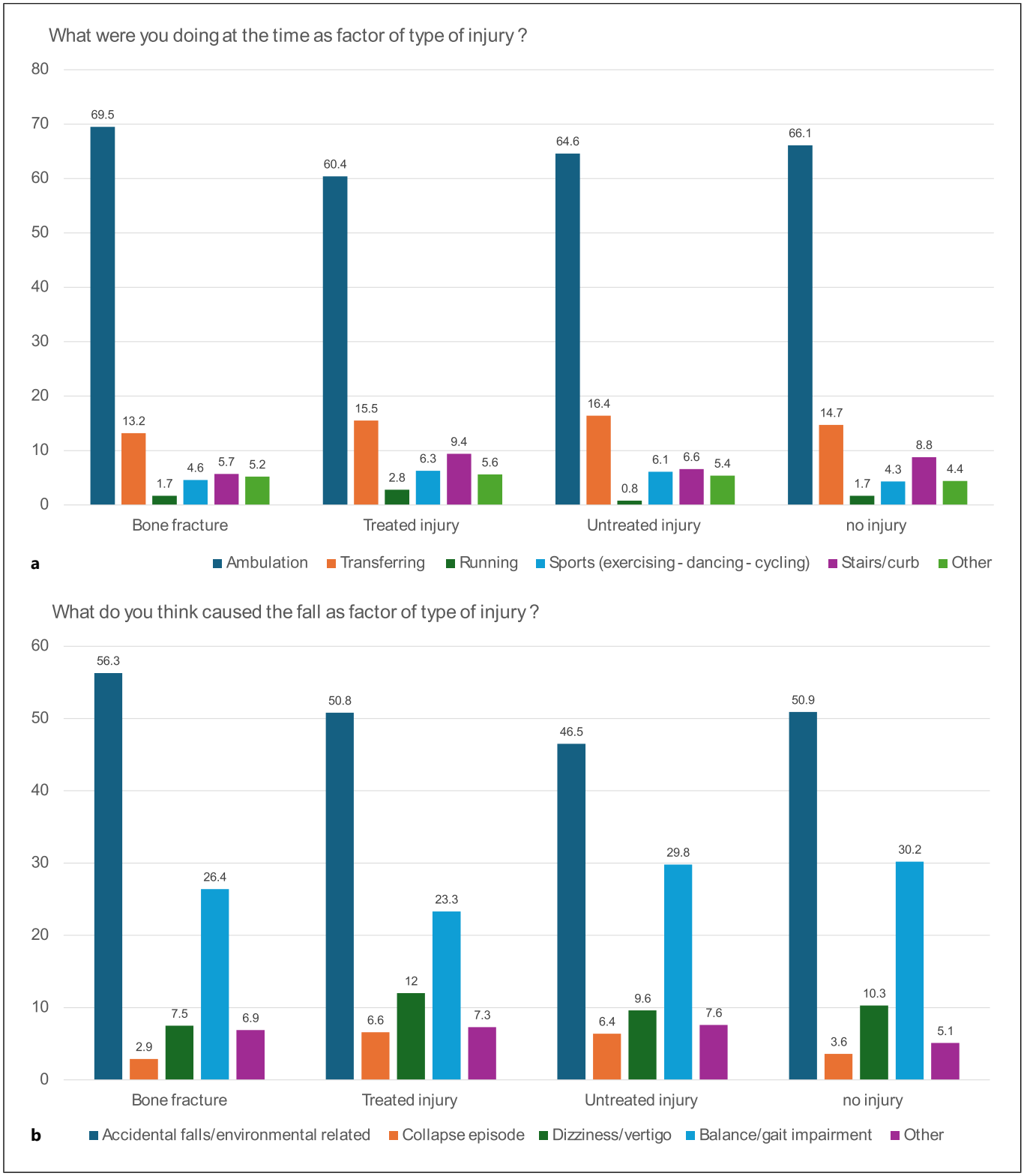
Out of the total 2,508 falls recorded during the study period (F0, FU12, and FU24), 1,568 occurred among women, and 940 were experienced by men. Descriptive statistics were used to characterize the cohort based on sexes, as detailed in Table 3. Women were older than men (80 vs. 79, $p = 0.043$), more likely to suffer from hip fracture (7.5% vs. 4.8%), osteoporosis (41.8% vs. 18%), and GDS >5 (21.4% vs. 14.7%). Men, however, were more likely to suffer from hypertension (80.9% vs. 76.7%), stroke (11.8% vs. 4.8%), COPD (18.2% vs. 12.6%), Parkinson's disease (3.7% vs. 1.8%), anemia (29.8% vs. 14.7%), and eGFR (23% vs. 20.9%). Also, men had a significantly higher hand grip strength (30 kg vs. 20 kg).

Figure 5 shows numerous distinctions emerged between women and men who reported a fall during the study period, for example, 39.7% of women experienced falls at home, compared to 34.1% of men. Of men who reported a fall, 58.2% fell outdoors, a slightly higher occurrence of falls compared to women, of whom 52.8% reported a fall outside their home (Fig. 5a). Figure 4b shows that women were more likely to report falls during ambulation activities (67.8%) and stair or curb interactions (13.9%), compared to men (59.5% and 7.7%, respectively). Conversely, men falls were more commonly associated with sports activities compared to women (9.1% versus 4.8%). The underlying causes of falls were generally similar between women and men (Fig. 5c). Nearly half of the falls among men resulted in no injury (49.9%), while the percentage was lower for women (37.4%). Figure 5d shows that a higher percentage of falls in women led to bone fractures (9.7% vs. 6.1% in men). Women also experienced a higher rate of falls resulting in injuries requiring treatment (22.8%) compared to men (17.3%).

In a logistic regression analysis (Table 4), we found that women were more likely to suffer from a severe injury, i.e., bone fracture, when they fell outdoors (Model 1, OR = 1.71, 95% CI = 1.09–2.68). After adjusting for anemia, the probability of severe injurious fall outdoors was somewhat higher (Model 5, OR = 1.82, 95% CI = 1.14–2.89). But when we adjusted for osteoporosis and hand grip strength (models 7 and 8), these models were no longer significant (Model 7, OR = 1.44, 95% CI = 0.90–2.30 and Model 8, OR = 1.31, 95% CI = 0.73–2.34, respectively).

## Discussion

The findings of this study offer valuable insights into the circumstances, location, activities and consequences of falls among independent community-dwelling older adults. Of 1,754 older adults (average age 80 years old) with data on falls, 2,508 falls were reported, 938 falls were reported at baseline, 773 at FU12, and 797 at FU24. The fall rates of 53.5%, 44.1% and 45.4% (at baseline, FU12 and FU24, respectively) recorded by this study are comparable to the 50% typically reported for representative samples of community-dwelling older adults aged 80 years old [3, 18, 32, 33]. We also found that about 70% of falls resulted in a non-severe injury (42.1% non-injurious and 28.7% untreated injury, respectively), and 8.5% of all falls resulted in a severe injury (i.e., bone fracture). Our findings are in agreement with the data by previous research that reported that about 10% of falls

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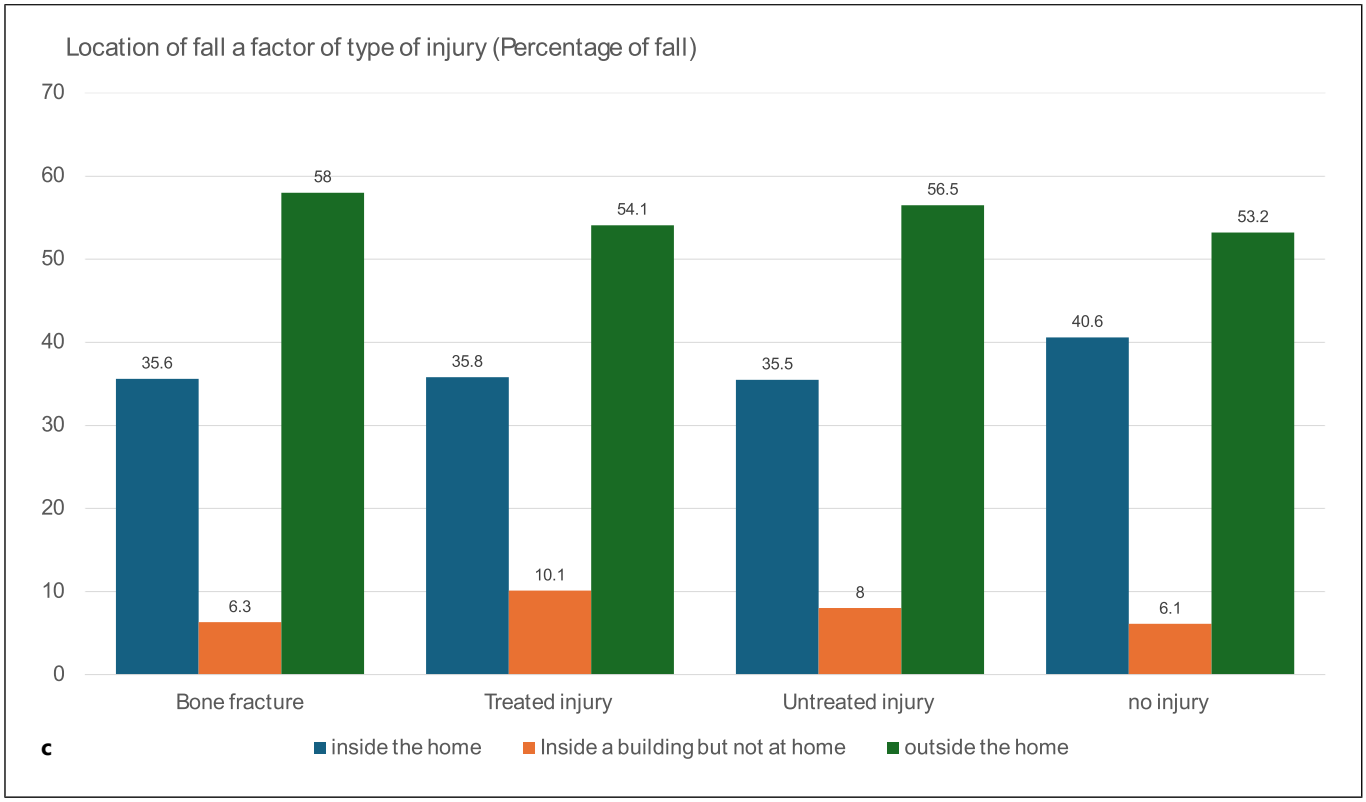



**Fig. 4.** Consequences of falls ($N$ = 2,056), bone fracture ($n$ = 174), treated injury ($n$ = 427), untreated injury ($n$ = 590), and no injury ($n$ = 865), presented as the percentage of self-reported cases for activities during fall (**a**), causes of fall (**b**), and location of fall (**c**).

among 75- to 84-year-old adults result in a severe injury which causes them to restrict their activities for a day or more or to seek attention from the healthcare system [1, 3].

*Circumstances and Causes of Falls*

We found that the most prevalent causes of falls were accidental falls due to environmental reasons, e.g., trips, slips or bumping into objects (50%) or due to balance and gait impairments (28.3%). In addition, we found that the majority of falls among independent older adults were due to falls that occurred during ambulation (64.6%). This is consistent with previous reports [10, 18, 34–38]. It was found earlier that the most common activities at the time of the fall were walking, walking up or down stairs and sit-to-stand transfer (49%, 11%, and 10%, respectively) [10]. Trips and slips or bumping into an object mostly occur unexpectedly and during walking, for example, the foot strikes the ground or carpet or an obstacle in its path during the swing phase of gait [10] or when the foot slips on an icy walkway during the stance phase of gait [39]. These unexpected balance losses often trigger balance recovery responses. Our findings suggest that older adults were unable to effectively recover from these unexpected balance losses. There are several strategies which could reduce the prevalence of slip and trip-induced falls among older adults. The first one is improving gait function and paying attention to obstacles that could cause a trip and slip [39, 40]; this could reduce the susceptibility to tripping or slipping, particularly on uneven and icy surfaces [41]. A second strategy would be performing balance training. A systematic review and meta-analysis that included 116 studies, involving 25,160 participants, showed that it can reduce the rate of falls by 23% [42]. The above balance training interventions involve pre-planned anticipatory postural adjustment functional exercises. But most falls in the present analysis happen during ambulation and unexpected balance loss. Therefore, perturbation-based balance training was developed. The perturbation-based balance training is a specific type of balance training where participants are

**Table 3.** Sociodemographic characteristics, clinical, laboratory parameters, and physical, cognitive, and emotional status, according to the gender of the fallers ($n$ = 2,508)

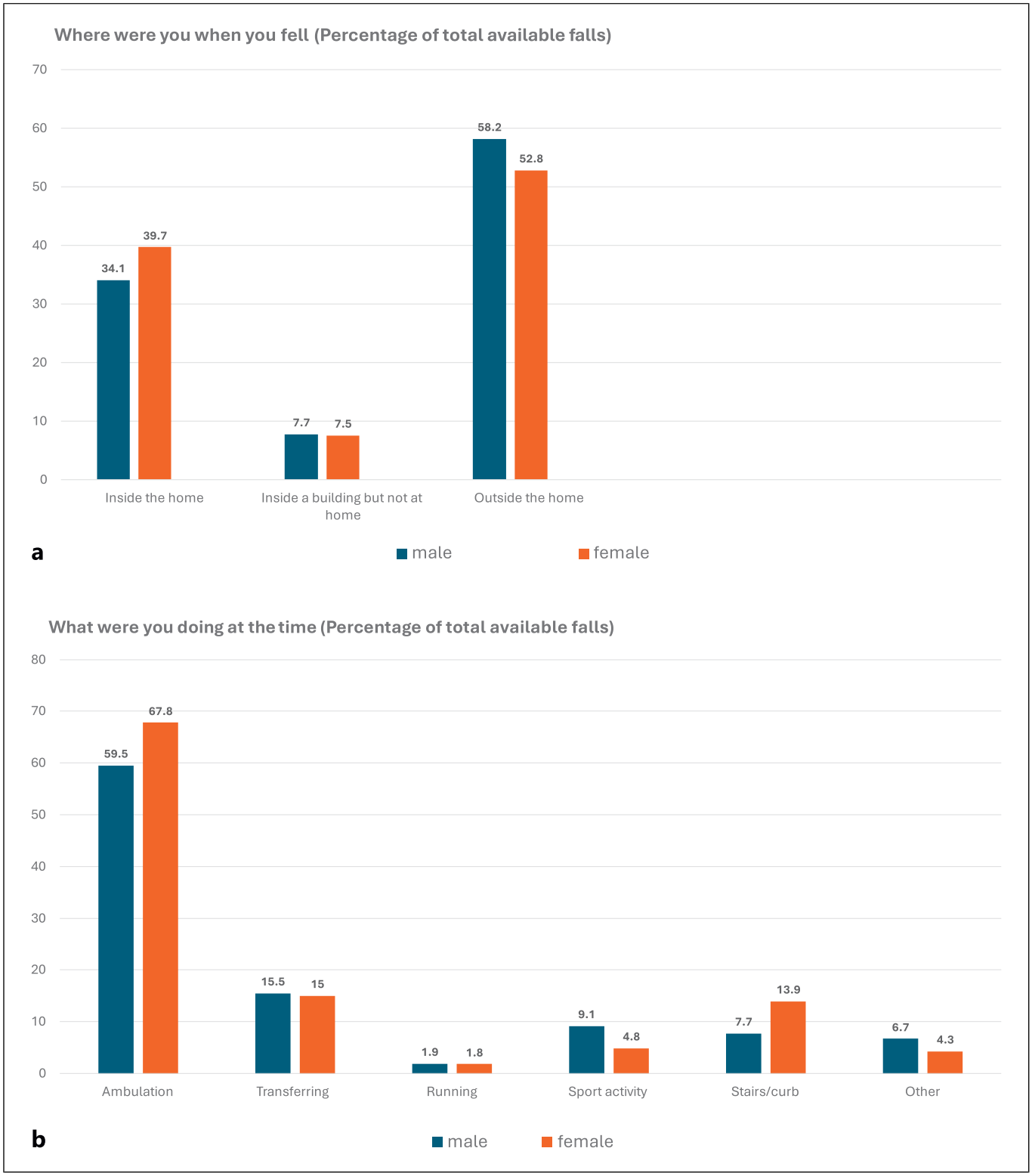
| Variable | Group A: women fallers ($n$ = 1,568) | Group B: men fallers ($n$ = 940) | $p$ value |
|---|---|---|---|
| Age, years | 80 (6) | 79 (7) | 0.043 |
| BMI, kg/m$^2$ | 27.5 (5.9) | 27.7 (5.3) | 0.721 |
| Marital status, $n$ (%) | | | <0.001 |
| Single | 124 (7.9) | 54 (5.7) | |
| Married/living with a partner | 510 (32.5) | 706 (75.1) | |
| Separated/divorced | 153 (9.8) | 47 (5.0) | |
| Widowed | 781 (49.8) | 133 (14.1) | |
| Education, years | 11 (7) | 11.5 (6) | 0.438 |
| Diabetes, $n$ (%) | 357 (22.8) | 291 (31.0) | <0.001 |
| Hypertension, $n$ (%) | 1,202 (76.7) | 760 (80.9) | 0.014 |
| Stroke, $n$ (%) | 76 (4.8) | 103 (11.0) | <0.001 |
| Hip fractures, $n$ (%) | 117 (7.5) | 45 (4.8) | 0.008 |
| COPD, $n$ (%) | 197 (12.6) | 171 (18.2) | <0.001 |
| Osteoporosis, $n$ (%) | 655 (41.8) | 169 (18.0) | <0.001 |
| Parkinson's disease, $n$ (%) | 29 (1.8) | 35 (3.7) | 0.004 |
| Anemia, $n$ (%) | 219 (14.7) | 265 (29.8) | <0.001 |
| CIRS | 9 (7) | 10 (7) | <0.001 |
| Take ≥5 current medications, $n$ (%) | 1,125 (71.7) | 692 (73.6) | 0.310 |
| LUTS moderate or big problems, $n$ (%) | 668 (42.6) | 321 (34.1) | <0.001 |
| eGFR (BIS equation), mL/min/1.73 m$^2$ | 56.5 (20.9) | 53.8 (23.0) | <0.001 |
| Hemoglobin, mg/dL | 13.3 (1.6) | 14.0 (2.2) | <0.001 |
| Hand grip strength, kg | 20 (7) | 30 (10) | <0.001 |
| GDS >5, $n$ (%) | 336 (21.4) | 138 (14.7) | <0.001 |
| MMSE <24, $n$ (%) | 104 (6.6) | 91 (9.7) | 0.006 |

Values are $n$ (%) for categorical variables, and median (interquartile range) for continuous. Data about falls during the whole study period: baseline, FU12, and FU24. NS, not significance; ADL, activities of daily living; BMI, body mass index; CIRS, Cumulative Illness Rating Score; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; GDS, Geriatric Depression Scale; iADL, instrumental activities of daily living; LUTS, lower urinary tract symptoms; MMSE, Mini-Mental State Examination.

frequently exposed to unannounced balance losses, aiming at evoking and improving balance reactive responses to avoid a fall. A meta-analysis that included 29 trials found that older adults who were assigned to reactive balance training groups reported 40–46% [43] fewer falls than control groups. In addition, home modifications, e.g., carpet edges, electrical cords, door thresholds, and taking care of hazardous obstacles outdoors, e.g., uneven flooring and defects, are important and found to reduce the prevalence of falls among older adults [44].

*Location of Falls*

In the present study, the majority of falls among independent older adults occurred outside the home (54.8%), 58.2% among men and 52.8% among women. A study reported that 48% of falls among adults aged 65–79 years occurred outdoors, including both community-dwelling older adults and care facility residents who visited emergency departments following a fall [10]. Another study reported that there are associations between increasing age and female gender with a higher number of indoor falls [12]. The controversial results may

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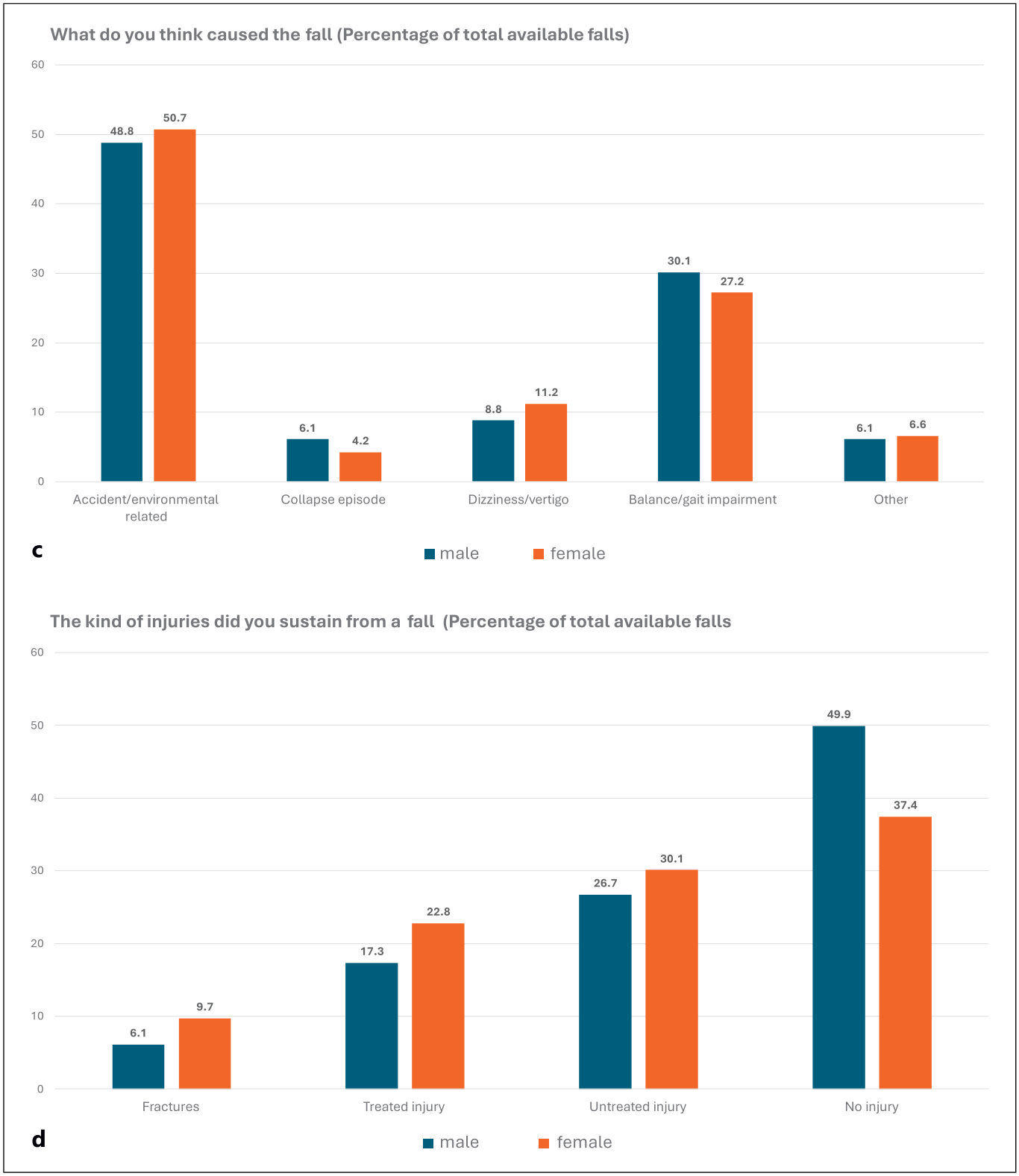


**Fig. 5.** Sex differences between woman ($N$ = 1,568) and man ($N$ = 940) presented as percentages for location of fall ($n$ = 2,067) (**a**), activity during fall ($n$ = 2,065) (**b**), causes of fall ($n$ = 2,064) (**c**), and consequences of fall ($n$ = 2,058) (**d**).

**Table 4.** Probability of a bone fracture due to a fall in older adults who fell inside their homes and in older adults who fell outside their homes

| Predictors | OR (95% CI) fell inside the home | OR (95% CI) fell outdoors |
|---|---|---|
| Model 1: sex | 1.52 (0.84–2.74) | 1.71 (1.09–2.68) |
| Model 2: Model 1 adjusted for GDS >5 | 1.44 (0.79–2.60) | 1.70 (1.08–2.66) |
| Model 3: Model 1 adjusted for hypertension | 1.52 (0.84–2.74) | 1.70 (1.09–2.67) |
| Model 4: Model 1 adjusted for stroke | 1.49 (0.83–2.70) | 1.73 (1.10–2.72) |
| Model 5: Model 1 adjusted for anemia | 1.53 (0.83–2.84) | 1.82 (1.14–2.89) |
| Model 6: Model 6 adjusted for CIRS, take ≥5 current medications | 1.47 (0.79–2.73) | 1.73 (1.08–2.77) |
| Model 7: Model 1 adjusted for osteoporosis | 1.15 (0.62–2.13) | 1.44 (0.90–2.30) |
| Model 8: Model 1 adjusted for hand grip strength | 1.59 (0.73–3.48) | 1.31 (0.73–2.34) |

CI, confidence interval; OR, odds ratio.

stem from two factors: the fall data were collected from emergency department records, excluding individuals who visited a general practitioner or did not seek medical care after a fall [10]. As a result, the study does not capture all falls among older adults. Another reason that might cause the difference is the more robust older adults in the SCOPE cohort, while other studies [10, 12, 25] consisted of an older and frailer population, in which most falls occurred indoors.

Our data also revealed that 54.7% of indoor falls resulted in an injury (8% bone fracture and 19.7% treated injury and 27% untreated injury), somewhat lower than the 59.1% of outdoor falls (9% bone fracture and 20.5% treated injury, and 29.6% untreated injury, Fig. 3c). A similar proportion of indoor and outdoor injurious falls was observed for older men, while older women experienced more indoor injurious falls [15]. Data from the National Health Interview Survey assessed the locations of medically treated fall injuries and found that older adults were more likely to seek medical treatment for fall injuries occurring indoors rather than outdoors [45]. Similarly, the most common location for fall-related emergency department visits among community-dwelling older adults was reported to be the home, especially those aged 85 and older [10]. It has also been previously shown that older adults tend to fall in locations where they spend the most time [30], and during periods of maximum activity [20, 21]. This suggests that older adults in the above studies were spending more time at home than in public places. The above studies are in contrast with the findings from studies of community-dwelling older adults in Japan and the UK [46, 47]. For example, 81% of injurious falls among older men and 51% of injurious falls among older women occurred outdoors in Japan [46]. A deeper observation of these studies [46, 47] shows that more indoor falls were observed among older adults who were frail, had poor health status and were leading an inactive lifestyle, whereas outdoor falls occurred more among active and mobile older adults [11, 46]. Also, those who had fallen outdoors had better health characteristics, whereas those who had fallen indoors were generally in poor health. For example, 25.5% of indoor-only recurrent fallers had lower gait speeds compared to 2.9% among outdoor-only recurrent fallers; the respective percentages were 44.7% and 8.8% for Berg balance score <48 [13]. Similarly, we found that, compared to outdoor fallers, the indoor fallers had higher proportions of people with hypertension, diabetes, stroke, and lower self-reported QoL (Table 2). In addition, the indoor fallers' blood examinations showed poorer health characteristics, e.g., anemia, lower hemoglobin, and higher serum creatinine, as well as a lower emotional condition (i.e., higher GDS). In addition, our results may suggest that older adults in the SCOPE cohort were more mobile and active since they fell outside their homes and ambulation was ranked as the most common activity, accounting for 65% of falls.

Furthermore, our multivariate logistic regression model shows that the probability of sustaining a severe injury from an outdoor fall was higher for women, with a 71% increase in the odds compared to men (Table 4, Model 1). Interestingly, when we adjusted the model for

osteoporosis or hand grip strength, the significance disappeared, suggesting that women without osteoporosis or with greater strength are protected from outdoor falls.

*Consequences of Falls*

The 8.5% fracture rate observed in this study is somewhat higher than the range of 3.5–6% reported earlier [18, 37]. The 20.7% rate of treated injuries in our study was also higher than the 9% soft tissue injuries requiring medical attention in previous reports [18, 35, 37]. This may result from the fact that in previous studies older adults were asked about soft tissue injuries while we asked whether any treatments were needed, which may not be at a medical facility. We also found that most bone fractures occurred during ambulation (69.5%), and outdoors (58.0%). Similarly, the most common outdoor activity during a fall was walking (66%) [10]. Also, older adults in our study reported that accidental falls resulting from a trip, slip, or bumping into object were the most frequent causes of a fall (50%, Fig. 2c). Also, as shown in Figure 4b, accidental falls were ranked as the most frequent cause of a bone fracture (56.3%) compared to 46.5% and 50.8% for less severe injurious falls, and non-injurious falls (50.9%). Additionally, our findings indicate that 58% of falls that resulted in bone fractures occurred outdoors, nearly double the proportion compared to those occurring at home, which accounted for 35.6% (Fig. 5c).

*Comparisons between Men and Women*

Several previous studies have reported higher fall rates for women than men [48–51]. This is also the case in the present study, where the percentages of women who fell were 61.0% ($n$ = 1,508) and 39.0% ($n$ = 940) for men (Table 3). There have been several reports of rates similar to ours [18, 35, 50]. Our study revealed several differences in the circumstances and consequences of falls between men and women. Men were twice as likely as women to fall during sports activities (9.1% vs. 4.8%, Fig. 5b). Compared to men, women were twice as likely to fall while descending stairs or tripping (7.7% vs. 13.9%) and more likely to fall during ambulation (59.5% vs. 67.8%). Men in our study fell outdoors more frequently than women (58.2% vs. 52.8%), likely due to spending more time outdoors [14, 40]. We found that women fell more often at home than men (39.7% vs. 34.1%), possibly due to accidental falls due to environmental reasons. This aligns with studies that found that older men reported spending more time engaged in recreational activities than older women, who otherwise reported spending more time doing light housework compared to older men [13, 37]. We believe these differences are related to the locations and unique hazards of certain environments. It was reported earlier that falls among women resulted from indoor trips, while men most often resulted from outdoor slips [18].

In the MOBILIZE Boston study, they found women had a higher rate of fall injuries overall and a higher rate of indoor fall injuries per person year than men [10]. However, it was reported that the percentages of adults aged ≥85 years reporting a fall-related injury were similar between women and men (14.3% vs. 13.4%) [16]. Our findings show about 30% more bone fractures in women compared to men (9.7% vs. 6.1%), suggesting that falling outdoors does not result in more severe injuries than falling at home. This suggests that lower bone density caused by osteoporosis increased the risk of bone fractures among women. In line with that, we found that the percentages of osteoporosis among women reporting a fall-related bone fracture were higher compared to men (41.8% vs. 18.0%).

The following limitations should be acknowledged when interpreting the results of our study. First, all fall data were gathered from self-reports, medical records, caregivers, or from electronic medical history; therefore, this study may not encompass all falls, specifically non-injurious falls, due to recall bias. Individuals may forget or misremember details about their falls, leading to inaccuracies in the data. Second, data were drawn from a defined relatively healthy community-based population; thus, these results cannot be generalized to weaker, frailer or institutionalized older persons. Third, it might be that there is a selection bias in assessing older volunteers (e.g., this may undermine the generalizability of the results obtained). Fourth, some data regarding either the falls, location or activity at the time of the fall was missing in our records, potentially introducing bias. Our research protocol did not include the measurement of daily steps; therefore, we were unable to determine the absolute number of falls in relation to exposure (i.e., fall rate per daily steps), which has been suggested as an important factor in understanding the influence of exposure on fall risk [52]. Another limitation of this study is that participants with depression or cognitive impairment may have had difficulty accurately reporting falls, potentially affecting data quality, despite efforts to support them with caregivers and medical records. Despite these limitations, the study provides valuable insights, especially for the subgroup of community-dwelling older men and women that were informed that this study is part of a 2-year prospective

investigation emphasizing the importance of accurately reporting of a fall, likely improved the accuracy of participants' fall reports. Strengths of this study include its large population size from 7 different countries and the detailed information on injuries sustained. Older adults that took part in the 3-year data collection of past falls (F0, FU12, and FU24) were extremely engaged, which may ensure a relatively high accuracy of the self-reports.

## Conclusion

This study identified distinct fall and injury patterns, including where and how falls leading to bone fractures occur in older men and women. Notably, 8–9% of the falls resulted in bone fractures in older adults, with an average age of 80 years, occurred both indoors and outdoors, mostly during ambulation, where accidental falls resulted from trips and slips, and about 30% more in women compared to men. These findings offer new insights into the patterns of injurious falls by age, sex, and injury type, and may help guide targeted fall prevention efforts and suggest ways of preventing falls. It is reasonable to recommend that older adults should inspect the surroundings for hazards, especially those which could result in unexpected balance loss from a slip or trip, as well as motivate them to train their balance and specifically train their balance recovery abilities.


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Dr. Pedro Gil was not available to confirm co-authorship, but the corresponding author, Dr. Paolo Fabbietti, affirms that Dr. Pedro Gil contributed to the article, had the opportunity to review the final version to be published, and guarantees Dr. Pedro Gil's co-authorship status and the accuracy of the author contribution and conflict of interest statements.


## Statement of Ethics

The study protocol was approved by the Ethics Committees at all participating institutions and complies with the Declaration of Helsinki and Good Clinical Practice Guidelines. Only baseline data are used in the present study. Ethics approvals have been obtained by the Ethics Committees in participating institutions as follows.

- Italian National Research Center on Aging (IRCCS INRCA), Italy, #2015 0522 IN, January 27, 2016.
- University of Lodz, Poland, #RNN/314/15/KE, November 17, 2015.
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## Conflict of Interest Statement

The authors declare no conflict of interest. The funder had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results. Patients were requested to sign a written informed consent before entering the study.


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## Author Contributions

E.F. and I.M. participated in data analyses design, data collection, and manuscript drafting and revision. P.F. contributed to data management and statistical analyses, manuscript drafting, and revision. R.K. contributed to manuscript drafting and revision. Y.M. coordinated study protocol and data collection and participated in manuscript drafting. F.L., S.B., and A.C.C. conceived the study, coordinated study protocol and data collection, and participated in manuscript drafting and revision. F.M.-R., L.T., J.A., A.C.C., R.R.-W., G.W., T.K., A.G., P.G., F.F., R.M.-G., and R.B.-R. participated in study protocol design, data collection, and manuscript drafting and revision.

## Data Availability Statement

Data will be available for SCOPE researchers through the project website (www.scopeproject.eu).

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