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Review Article

Understanding the Home Environment as a Factor in Mitigating Fall Risk among Community-Dwelling Frail Older People: A Systematic Review

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The home environment is increasingly emphasized as a key factor in home falls among frail older people. In this study, we aimed at exploring and synthesizing empirical studies that considered the environmental factors of home falls among frail older people. We performed a systematic review to draw comprehensive conclusions regarding these environmental factors by searching MEDLINE, CINAHL, Embase, and Cochrane Library, as well as gray literature databases. Intervention and nonintervention studies that specifically reported home environmental factors related to falls in community-dwelling frail older people aged 65 years and over were selected. Of the 8374 studies initially retrieved, seven intervention and seven nonintervention studies were included in the analysis. In seven of the 14 studies, environmental hazards were evaluated using relevant assessment tools. Interventions were provided for the bathroom/toilet, bedroom, living room, and for slipping and tripping, identified as frequent fall locations and situations, respectively, through nonintervention studies. The most common intervention was to provide advice/counseling and disseminate information to enhance knowledge after visiting the home and evaluating the home environmental factors that could affect falls. In the majority of the studies, the intervention was of a multicomponent nature, and in only two intervention studies was there practical modification of the home environment to lower the fall risk. In all the four studies with statistically significant results, the intervention was provided by a multidisciplinary team. Through this review, we identified environmental factors for home falls, helping clinicians and health professionals gain a better understanding of the situation to prevent recurrence in frail older people who have experienced falls. The findings indicate that comprehensive standardized environmental evaluations should be conducted considering older people's functional characteristics and needs and that the intervention process requires the participation of older people with a multidisciplinary team.

1. Introduction

Falls are a leading cause of unintentional injury and death among older people [1]. As per reports, one-third of community-dwelling people aged 65 and older experienced a fall at least once a year [2, 3]; half of them experienced two or more falls [4]. More than two-thirds of the falls among older people in South Korea occurred at home, often in the bedroom and living room, which are daily living spaces [5]. These data show community-dwelling older people's high vulnerability to falls. As falls are preventable health problems, it is important to make efforts to reduce falls that can occur during daily life at home [6]. Identifying risk factors related to falls and providing appropriate interventions [7] can help older people in maintaining their health and independent lifestyle [8].

Frailty is a condition that impairs physical and cognitive abilities, increasing the possibility of adverse health outcomes [9]. Fried et al. [10] identified the five characteristics of frail older adults as unintentional weight loss, weakness, poor endurance and energy, slowness, and low physical activity level. A systematic review revealed the association between frailty and falls in older people [11]. Falls have a complex etiology of risk factors, including environmental, situational, biological, behavioral, and socioeconomic risk factors [1, 12]. As fall risk escalates with an increasing number of risk factors [13], frail older people with impaired physical and cognitive abilities may have a higher fall risk than those without such impairments.

Frail older people are unable to react rapidly and effectively when faced with sudden environmental changes, causing them to lose balance [14, 15]. While nonfrail older people have a high exposure to outdoor environmental risks, frail older people are exposed to indoor environmental risks, which need to be reduced to minimize home falls [16]. Therefore, it is necessary to identify environmental risk factors among frail older people. Modifications of the home and avoiding dangers in the home environment are essential elements of fall prevention [17] for frail older people.

In some systematic reviews, there have been efforts to identify the efficacy of the environmental approach for reducing home falls [18, 19]. Clemson et al. [18] confirmed that home environment intervention is effective in preventing home falls among older people living in the community. Gillespie et al. [20] found that home safety interventions reduce the rate of falls and the risk of falling. Hopewell et al. [21] concluded that multifactorial interventions may reduce the rate of falls compared with usual care or attention control and that those environmental interventions are one of the commonly applied or recommended interventions for multifactorial interventions. Chase et al. [19] found that it was important to designate a population that would particularly benefit from fall reduction interventions, such as frail older people, and suggested that more studies investigating the effects of home modification on fall prevention were needed. As a result of reviewing the previous studies, it has been confirmed that environmental interventions could be meaningfully used to reduce home falls in community-dwelling frail older people. However, because the previous systematic reviews did not reach an integrated conclusion on ways to specifically improve and apply interventions, the scope of the review needs to be expanded. Therefore, in this article, we reviewed studies with various designs to draw comprehensive conclusions about the environmental factors related to home falls. At the same time, we seek to clarify the interpretation and application of the results by focusing on frail older people, who can greatly benefit from environmental interventions.

We aimed to explore and synthesize empirical research, including both intervention and nonintervention studies, that reported the environmental factors related to home falls among community-dwelling frail older people. The following research questions guided the review: (1) what are the environmental risk factors associated with home falls in community-dwelling frail older people? and (2) which environmental factors have been considered in interventions for home falls?

2. Materials and Methods

This systematic review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [22].

2.1. Data Sources and Search Strategies. The search, the strategy for which was reviewed by medical librarians, was conducted on April 13, 2023, using four electronic databases: MEDLINE, CINAHL, Embase, and Cochrane Library. We also searched for gray literature through the Virginia Henderson International Nursing Library. We developed a list of key search terms and controlled vocabulary to search for articles containing all the following concepts: (1) "aged" AND "frailty," (2) "risk factors" OR "home environment," (3) "accidental falls," and (4) "community"-without limitations on the study type, language, or date of publication. In addition, the references listed in each identified article were screened and manually searched to obtain more comprehensive results. The search strategies and search results from each database can be found in Supplementary Material 1.

2.2. Study Selection. Four authors screened titles and abstracts based on the inclusion criteria and independently double-reviewed the full text of the studies (Figure 1).

2.2.1. Inclusion Criteria. The inclusion criteria for this systematic review were as follows: (1) studies in which the participants were community-dwelling frail older people aged 65 years and over (the following cases were also considered studies targeting frail older people: studies in which participants were termed "frail older people" and a study on older people with the characteristics of frailty such as Fried et al.'s [10] criteria even though they were not clearly target termed frail older people), (2) outcomes related to falls (such as fall occurrence or number), and (3) studies specifically reporting home environmental factors related to falls.

2.2.2. Exclusion Criteria. The exclusion criteria were as follows: (1) studies in which the participants were older people living in hospitals and nursing homes; (2) studies in which the participants' age was not clearly reported; (3) studies in which the participants were older people without frailty-related variables; (4) outcomes measuring not falls but fear of falls; (5) studies that did not use a quantitative (randomized controlled trial [RCT], nonrandomized, observational [cross-sectional or longitudinal/cohort]) design; (6) instrument development study or protocol; and (7) nonreporting of study methods.

2.3. Data Extraction. The researchers had an acceptable level of agreement of over 95% regarding the final selection of the studies. The same four authors extracted data from the selected studies into an analysis table, and disagreements were resolved by a separate author. The data were extracted

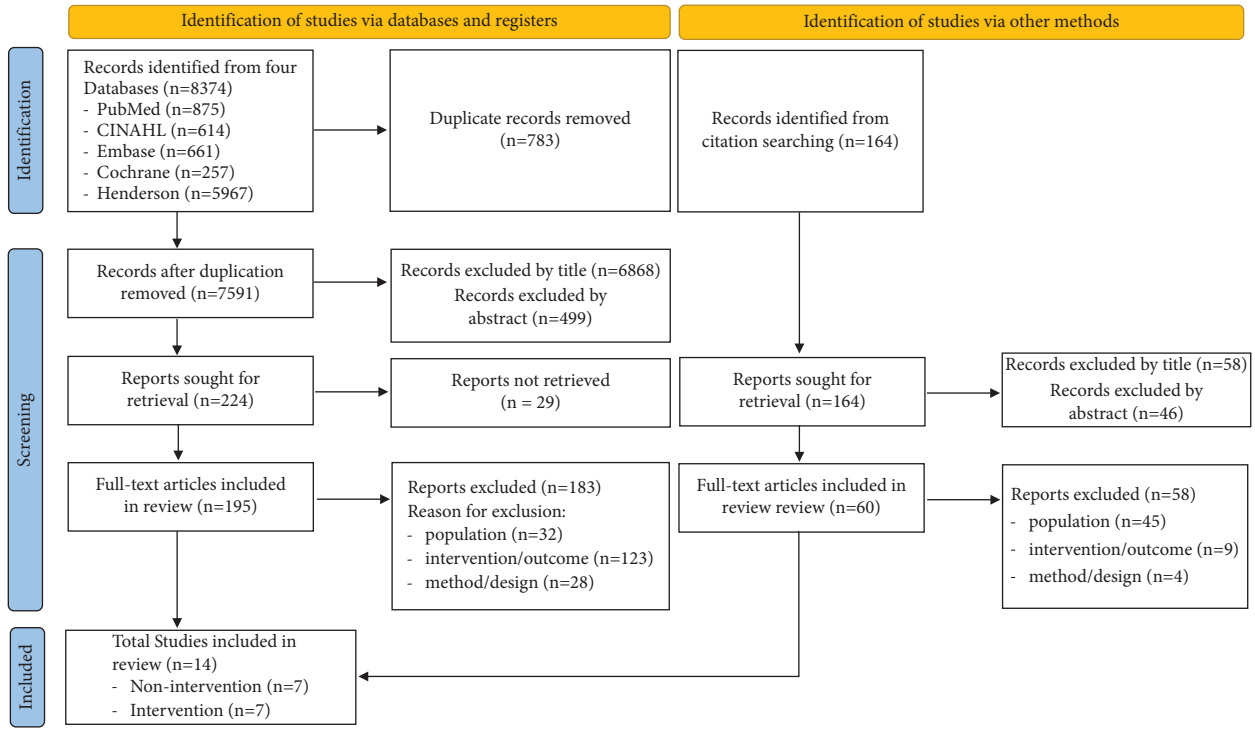

Figure 1: PRISMA flow diagram.

by dividing the studies into interventions and non-interventions to answer the broad research questions.

2.4. Methodological Quality Appraisal. The Mixed Methods Appraisal Tool (MMAT) version 2018 [23] was used for quality assessment. The MMAT was developed to evaluate the methodological quality of studies of various designs, such as RCTs and nonrandomized studies. Two authors independently appraised the studies for the methodological criteria and five quality criteria of the MMAT, which could be applied depending on the study design. Quality scores ranged from 0% if none of the criteria were satisfied to 100% if all criteria were met [24]. Studies included in this review fulfilled at least 60% of the criteria. The specific criteria of the MMAT and quality assessment of each study are presented in Supplementary Material 2.

2.5. Synthesis of Results. We used our review questions to guide data synthesis. To provide a comprehensive overview of the connections between nonintervention and intervention studies, we mapped environmental risk factors for community-dwelling older people's home falls in a table and examined whether these factors were considered in interventions for reducing home falls.

In Table 1, by design, studies are classified as intervention or nonintervention and the characteristics indicating participants' frailty are described. In addition, as falls may be related to regional characteristics [31, 39], country and community settings were described. Table 2 summarizes the environmental risk factors associated with home falls identified in nonintervention studies. After describing the contents of "environmental risk factors," these were analyzed secondarily and divided into risk location and situation. The most frequently identified risk location (bathroom/toilet, bedroom, and living room) and risk situations (slipping and tripping) were separated and organized. Table 3 summarizes the environmental interventions used to reduce home falls. We summarized the intervention details as presented in each study as well as whether the interventions had multiple components or only an environmental perspective. If the intervention considered specific locations or situations in the home, this was described to integrate it with nonintervention studies later by organizing the contents. In addition, by summarizing the methods for evaluating environmental characteristics in all the included studies, we considered whether the items were evaluated objectively.

3. Results

3.1. Search Results. Of the 8374 identified studies, 6868 titles and 499 abstracts were reviewed for relevance. Of these, 195 full-text studies were reviewed for eligibility and 12 studies met the inclusion criteria. Two additional studies that met the inclusion criteria were found in the citation search. Finally, 14 studies were included for synthesis (Figure 1).

3.2. Characteristics of the Included Studies. Table 1 shows the characteristics of the 14 studies. Seven (50%) were nonintervention [25–31] and seven (50%) were intervention studies [32–38]. The 14 studies were conducted in various regions (four each in the US, Asia, and Europe), and the countries where both nonintervention and intervention

Table 1: Characteristics of the included studies ($N = 14$).

1st author (year)	Country	Study design	Community setting	Sample size, age	Participants' characteristics (frailty assessment tool)
Ha et al. (2021) [25]	Vietnam	Cross-sectional	No description	$n = 539$, age = 69.4 ± 7.5	Older people who visited the outpatient department of the hospital ([a]Fried criteria)
Henwood et al. (2020) [26]	USA	Cross-sectional	City	$n = 237$, age = 57.7 ± 6.4 (range: 45–80)	Older people living in permanent supportive housing ([a]Fried criteria)
Maan et al. (1996) [27]	USA	Retrospective	No description	$n = 392$, aged 60 or older (i) Persons with falls: $n = 186$, age = 75.3 ± 8.3	Older people considered to be "at risk" of needing assistive devices or environmental interventions (ADL, IADL)
Northridge et al. (1995) [28]	USA	Prospective	City	$n = 266$, aged 60 or older	Frail older people who fell at least once in the previous year ([b]frailty scale)
Pi et al. (2015) [29]	China	Cross-sectional	City	$n = 190$, age = 79.5 ± 7.4	Frail older people ([a]Fried criteria, walking independently)
Tuvemo Johnson et al. (2022) [30]	Sweden	Longitudinal, descriptive design	No description	$n = 175$, age = 83.2 ± 4.6 (i) No falls in 12 months: $n = 101$, age = 83.4 ± 4.7 (ii) One or more falls in 12 months: $n = 74$, age = 82.8 ± 4.6	Older community-dwelling adults who needed walking aids or home help service (assistance with daily activity, walking aids, physical activity, fall history, SPPB, [c]Mini BESTest, walking speed, grip strength)
Yoo et al. (2016) [31]	Korea	Cross-sectional	City, rural	$n = 534$ (i) City: $n = 226$, age = 77.7 ± 6.48 (ii) Rural: $n = 308$, age = 78.1 ± 6.16	Frail older people (visiting health care survey)
Gill et al. (2002) [32]	USA	RCT	No description	(i) Exp: $n = 94$, age = 82.8 ± 5.0 (ii) Con: $n = 94$, age = 83.5 ± 5.2	Physically frail older people (rapid gait test, stand up with arms folded)
Hollinghurst et al. (2022) [33]	UK	Nonrandomized (retrospective longitudinal controlled nonrandomized intervention cohort study)	No description	$n = 657{,}536$, age = 72 ± 8.8 (i) Exp: $n = 123{,}729$, age = 78.04 ± 8.52 (ii) Con: $n = 533{,}807$, age = 70.6 ± 8.25	Mild, moderate, or severe frailty ([d]electronic frailty index)
Luck et al. (2013) [34]	Germany	RCT	No description	(i) Exp: $n = 118$. age = 85.4 ± 3.6 (ii) Con: $n = 112$, age = 85.2 ± 3.5	Older people with functional impairment (ADL)
Nikolaus and Bach (2003) [35]	Germany	RCT	City	$n = 360$, age = 81.5 ± 6.4	Frail older people showing functional decline, especially in mobility (ADL, immobility, and chronic diseases)
Tchalla et al. (2013) [36]	France	Dynamic random allocation (pilot study)	City	$n = 96$, age = 86.6 ± 6.5 (i) Exp: $n = 49$ (ii) Con: $n = 47$	Patients with mild and moderate Alzheimer's disease (registered on the frail older people)
van Haastregt et al. (2000) [37]	The Netherlands	RCT	No description	(i) Exp: $n = 159$, age = 77.2 ± 5.1 (ii) Con: $n = 157$, age = 77.2 ± 5.0	Older people already mildly impaired in mobility or with increased risk of falling (fall history, MCS)
Yoo et al. (2013) [38]	Korea	Nonrandomized (nonequivalent control group pretest-posttest design)	Rural	$n = 60$, age = 77.0 ± 5.1 (i) Exp: $n = 30$, age = 75.8 ± 4.3 (ii) Con: $n = 30$, age = 78.2 ± 5.7	Frail elders living at home (visiting health care survey)

ADL: activities of daily living; Con: control group; Exp: experimental group; IADL: instrumental activities of daily living; MCS: mobility control scale; SAIL: secure anonymized information linkage; SPPB: short physical performance battery. [a]Fried criteria: unintentional weight loss, weakness, exhaustion, slow gait, and low physical activity. [b]Frailty scale was assessed by structured interview, physician's examination, neuromuscular performance, vision, and mental status. [c]Mini BESTest: the balance evaluation systems test; [d]Electronic frailty index assigns a frailty score calculated using 36 variables from primary care data including symptoms, signs, diseases, disabilities, and abnormal laboratory values, referred to as deficits.

Table 2: Environmental risk factors associated with home falls identified in nonintervention studies ($N = 7$).

1st author (year)	Fall measures (period)	Environmental factor assessment	High risk location				High risk situation			Study findings (environmental factor and falls)
			Bathroom/toilet	Bedroom	Living room	Others	Slipping	Tripping	Others	
Ha et al. (2021) [25]	(i) Rate of falls (ii) Fall number (1 year)	(i) Location of falls (ii) Fall circumstances	Yes	N/A	N/A	N/A	Yes (i) Slippery floors	N/A	N/A	(i) Majority of falls occurred at home (69.6%), mainly in bathrooms (ii) High percentage of falls (51.6%) caused by slippery floors
Henwood et al. (2020) [26]	(i) Rate of falls (ii) Fall number (1 year)	(i) Location of fall	Yes	N/A	N/A	N/A	N/A	N/A	N/A	(i) 44% fell at home, of whom nearly half fell in bathrooms
Maan et al. (1996) [27]	(i) Rate of falls (ii) Fall number (5 years)	(i) [a]Home assessment instruments	N/A	N/A	N/A	N/A	N/A	Yes (i) Clutter	Yes (i) Lack of handrails c Cabinets too high	(i) Those who reported falling had a significantly higher number of environmental problems
Northridge et al. (1995) [28]	(i) First fall (1 year)	(i) [b]Home hazard scale (ii) [c]Individual environmental survey items	Yes (i) Lack of safety features in bathroom (ii) Lack of nonslippery surfaces in bathtub (iii) No grab bar in bathtub, and for toilet (iv) Loose or wobbly grab bars)	Yes (i) Trouble getting in/out of bed	Yes (i) Chairs/ sofas too low/ too soft	N/A	Yes (i) Rugs in hallways not secured to floor (ii) Small rugs in bathroom not slip resistant (iii) Nonslippery surfaces in bathtub	Yes (i) Clutter: objects stored on floor even temporarily (ii) Clutter: having to avoid furniture/ objects	Yes (i) Problems in transfer (ii) Trouble getting in/out of bed (iii) Difficulty getting in/out of chairs/sofas (iv) Use furniture to support self when walking	(i) 34.2% of women and 30.5% of men experienced one or more nonsyncopal falls at home (ii) First falls more likely to have environmental component than later falls (iii) First falls in various settings; later falls largely confined to bedroom (iv) Frail individuals more than twice likely as vigorous individuals to fall during the follow-up

Table 2: Continued.

1st author (year)	Fall measures (period)	Environmental factor assessment	High risk location				High risk situation			Study findings (environmental factor and falls)
			Bathroom/toilet	Bedroom	Living room	Others	Slipping	Tripping	Others	
Pi et al. (2015) [29]	(i) Rate of falls (1 year)	(i) Location of falls (ii) Cause of fall	Yes	Yes (i) Especially for women	Yes (i) Especially for men	Yes (i) Parlour (especially for men)	Yes (i) Walking on wet floor or snowy ground	Yes (i) Walking on air or on ground	Yes (i) Morning	(i) Most (67.9%) falls occurred indoors (ii) Approximately half of fracture injuries occurred indoors (65–79 age group) (iii) Higher proportion of indoor falls occurred among 80+ year-olds (iii) Bedroom and toilet most common places for indoor falls (women in bedroom, men in parlour) (iv) Approximately 42% of falls occurred in the morning (v) Tripping and slipping accounted for 95.8% of extrinsic factors in falls; tripping most common extrinsic factor (70.5%)
Tuvemo Johnson et al. (2022) [30]	(i) Rate of falls (ii) Fall number (1 year)	(i) Location of falls (ii) Perceived cause of falls	Yes	Yes	Yes	Yes (i) Hall (ii) Other rooms or garage (iii) Kitchen (iv) Undefined indoors at home	Yes (i) Slipped in socks/slippers	Yes (i) Stumbled: on an object or just stumbled	Yes (i) Moving/uneven ground (ii) Environment disturbance/ affection (iii) Reduced vision/light	(i) Location of falls at home are as follows: bedroom > living room > bathroom > hall > other rooms or garage > kitchen > undefined indoors at home (ii) Most of the falls in this group of older adults occurred indoors at home in the bedroom or in the living room (iii) The most common activities connected with the falls were moving around within the home and changing the body position, especially when rising from sitting to standing
Yoo et al. (2016) [31]	(i) Rate of falls (ii) Fall number (1 year)	(i) [d]Home environment safety assessment tool	N/A	N/A	N/A	Yes (i) Rural-dwelling	N/A	N/A	N/A	(i) Rural-dwelling older people experienced significantly more falls than urban counterparts (ii) Rural-dwelling older people had significantly lower home environment safety score than urban counterparts

[a]Home assessment instruments include a section in which subjects are asked to describe problems they have with all environmental aspects of their home. [b]Home hazard scale was composed of storage problems, clutter, and hall rug problems. [c]Individual environmental survey items do not necessarily represent home hazards but are part of a self-administered home survey. This survey assessed bathrooms (no grab bar for toilet and loose or wobbly garb bars), bedrooms (trouble getting in/out for bed), and living/family rooms (difficulty with chairs/sofas and use of furniture for support). [d]Home environment safety assessment tool assessed living room (carpet and floor), furniture (bed, chair, and sofa), light (light is bright), bathroom (handrail and antislip mat), kitchen (location of frequently used objects), stairs (safety handrails and outline of the edge), and mobility (shoes and slippers).

Table 3: Environmental interventions to reduce home falls ($N = 7$).

1st author (year)	Fall measure	Detail of environmental intervention	Environmental factor assessment (assessment tool)	Multicomponent intervention	Provider	Intervention period/frequency/ follow-up period	Control group
Gill et al. (2002) [32]	(i) Rate of falls (≥1 fall)	(i) Home visit (1) Assessment of the presence of environmental hazards (2) Recommended intervention (training in proper use of assistive devices; removal of environmental hazards; removal of loose rugs, cords, and clutter in walking paths; placement of nonskid mats in bathroom and at kitchen sink; improvement in lighting; repair of walking surfaces, stairways, and railings; and installation of adaptive equipment in bathroom) (ii) Follow-up call to answer questions and provide encouragement	Yes ([a]Home environment survey)	Yes	Exp: physical therapist con: health educator	Home visit: 6 months/ 16/3, 7, and 12 months call: 6 months/6/3, 7, and 12 months	Educational programme to provide attention and health education
Hollinghurst et al. (2022) [33]	(i) Rate of falls; (ii) Fall number; (iii) Emergency admissions for falls	(i) Home adaptation interventions for fall prevention (1) Falls on a level, e.g., grab rails, floor coverings, and handrails (2) Falls on stairs, e.g., bannister, stair rail, and stairlift (3) Falls between level, e.g., step lift, external rails, and ramp (ii) Falls in the bathroom or bedroom, e.g., level access shower, bathroom redesign, and hoist (iii) Cold homes, e.g., boiler repairs, central heating, and heating repairs	Yes ([b]No assessment tool used)	Yes	No description	Charity work with the government, local authorities, and private companies; follow-up periods of up to 5 years	No intervention

Table 3: Continued.

1st author (year)	Fall measure	Detail of environmental intervention	Environmental factor assessment (assessment tool)	Multicomponent intervention	Provider	Intervention period/frequency/ follow-up period	Control group
Luck et al. (2013) [34]	(i) Fall number	(i) Geriatric assessment, case review, home counseling visits, and booster sessions (1) Guidance, verbal information, and/or informative materials (2) Obstacles and facilitators to adherence assessed, recommendations re-emphasized, and further assistance provided (3) Individualized interventions and recommendations supplemented by general information including causes of falls including home hazards (e.g., poor lighting, inappropriate footwear, and tripping hazards) and options to reduce the risk of falling and consequent injuries (e.g., installing bright lighting, wearing antislip shoes, removing hazards such as carpet edges) (4) Encouraged to check and eliminate risk factors for falling with the assistance of relatives	Yes ([c]No assessment tool used)	Yes	Multidisciplinary teams (nurse, scientist, psychologist, gerontopsychiatrist, nutritionist, and social worker)	About 1.5 months/3/ 18 months	No preventive home visits

Table 3: Continued.

1st author (year)	Fall measure	Detail of environmental intervention	Environmental factor assessment (assessment tool)	Multicomponent intervention	Provider	Intervention period/frequency/ follow-up period	Control group
Nikolaus and Bach (2003) [35]	(i) Fall number (no or 1 fall, ≥2 falls)	(i) Diagnostic home visit (ii) Assessing home for environmental hazards (iii) Advice about changes (shower seat, emergency call, grab bars, night light in bedroom/bath, antislipping mat in bathtub, elevation of bed, rollator, elevation of toilet seat, removal of rugs/ carpets, and removal of obstructions in walkways) (iv) Offer of facilities for home modifications (v) Training in use of technical and mobility aids	Yes ([d]Standardized home safety checklist)	No	Home intervention team (nurse, physiotherapist, occupational therapist, social worker, and secretary)	3 months/2.6 (range 1–8)/12 months	No type of home visit
Tchalla et al. (2013) [36]	(i) Rate of falls (ii) Fall number (1 fall, ≥2 falls)	Equipped HBTec-TS (home-based technologies coupled with tele-assistance service) system (i) Nightlight path for preventing falls	No	Yes	Researcher physician, social worker, geriatrician	12 months/irregular/ 12 months	Fall reduction programme only. No HBTec-TS system
van Haastregt et al. (2000) [37]	(i) Fall number (at least 1 fall, ≥2 falls)	(i) Home visit (ii) Screened for environmental factors potentially influencing falls and mobility (iii) Advice, referrals, and other actions aimed at dealing with hazards	Yes ([e]Home-safety checklist of indoor fall risk)	Yes	Community nurse	12 months/5/18 months	Usual care

Table 3: Continued.

1st author (year)	Fall measure	Detail of environmental intervention	Environmental factor assessment (assessment tool)	Multicomponent intervention	Provider	Intervention period/frequency/ follow-up period	Control group
Yoo et al. (2013) [38]	(i) Rate of falls (ii) Fall number	(i) Fall prevention programme for frail older people (ii) Home environmental safety investigation (iii) Intervention to advance knowledge related to cause of fall and ways to prevent falls: recognition of the importance and assessment of home environment hazards and improvement of home environment (modifying risk factors of lighting, stairs, house floor, bathroom, and kitchen)	Yes ([f]Home environment safety assessment tool)	Yes	Visiting nurses	8 weeks/8/2 months	Case management only. No fall prevention programme

Con: control group; CI: confidence interval; ED: emergency department; Exp: experimental group; IRR: incidence rate ratio; OR: odds ratio; F/U, follow-up. [a]Home environment survey assessed tipping hazards (throw rugs, clutter, cords/wires, holes, and carpet folds), type of flooring (carpet, hard surface, and hazardous), hazardous chair, light switch hazard, storage areas (number of storage areas, too high, too low, and ideal height), and bathroom particulars (grab bars in bath, grab bars in toilet, raised toilet seat, and bath floor surface). [b]No assessment tool used, only presented some examples of subtype of fall location and situation. [c]No assessment tool used, only presented some examples of home hazards (e.g., poor lighting, inappropriate footwear, and tripping hazards) and options to reduce the risk of falling and consequent injuries (e.g., installing bright lighting, wearing antislip shoes, and removing hazards such as carpet edges). [d]Details not provided. [e]Home-safety checklist of indoor fall risk assessed the floors, lighting, walking space, stairs, obstacles to the entrance, stairs, kitchen, bathroom, toilet, bedroom, living room, and loft and cellar. [f]Home environment safety assessment tool assessed living room (carpet and floor), furniture (bed, chair, and sofa), light (light is bright), bathroom (handrail and antislip mat), kitchen (location of frequently used objects), stairs (safety handrails and outline of the edge), and mobility (shoes and slippers).

studies were conducted were the US [26–28, 32] and South Korea [31, 38]. Among the nonintervention studies, four were cross-sectional, two were retrospective, and one was prospective. Among the intervention studies, five were RCTs [32, 34–37] and two were non-RCTs. Of the 14 studies, five included city-dwelling participants [26, 28, 29, 35, 36], one included rural-dwelling participants [38], and one included both city- and rural-dwelling participants [31]. However, seven studies did not clearly describe the community settings. Through this analysis, it was confirmed that Fried's criteria [25, 26, 29], visiting healthcare survey [31, 38], a frailty scale [28], and an electronic frailty index [33] were used to measure frailty. Furthermore, decline in activities of daily living, need for walking aids or home help service, impairments in mobility or having an increased risk of falling, immobility, and chronic disease were recognized as characteristics of frail participants.

3.3. Environmental Risk Factors Associated with Home Falls. Environmental risk factors associated with home falls in community-dwelling frail older people were identified in seven nonintervention studies (Table 2). In all the studies, falls were measured as the rate of falls and/or fall number. In six studies, falls were measured during one year and in only one study [27], over five years. To understand fall-related environmental factors, in three studies [27, 28, 31], home hazards were measured using related scales and in four studies, fall location was measured in the home. Regarding environmental risk factors, in five out of seven studies, the location in the home where most falls occurred was reported. An analysis of nonintervention studies showed that the location where the risk of home falls was emphasized was the bathroom/toilet [25, 26, 28–30], bedroom [28–30], and living room [28–30].

3.4. Environmental Intervention to Reduce Home Falls

3.4.1. General Characteristics of Environmental Intervention. Environmental interventions to reduce home falls were identified in seven intervention studies (Table 3). In all the studies, falls were measured based on the rate and/or number. However, it was difficult to synthesize the results because the form of the outcome presented in each study was different: at least one fall, ≥2 falls [36, 37]; no or one fall, ≥2 falls [35]; or ≥1 fall [32]. Environmental intervention was provided in all studies; only environmental intervention was provided in one study [35], while multicomponent interventions were provided in the other six. In three studies [34–36], interventions were provided by a multidisciplinary team, and in another three studies, interventions were provided by single expert groups such as nurses [37, 38] or physical therapists [32]. There were four studies [33–36] in which the effect of the intervention was statistically significant and three studies in which it was not. In all the four studies where the results were significant, the intervention was provided by a multidisciplinary team. The intervention period varied from eight weeks to 18 months, except for a retrospective longitudinal controlled nonrandomized intervention cohort study [33]. The frequency of intervention was 2.6–16; as the intervention in two studies [33, 36] was provided irregularly, the frequency could not be determined. In only one study [38], the time per session, i.e., 80 minutes, was provided. The follow-up period was 2 to 18 months. In three studies [32, 35, 36], the evaluation was conducted after 12 months and in two studies [34, 37], after 18 months. In four studies [32, 36–38], the control group received care as usual (Table 3).

3.4.2. Contents of the Environmental Intervention. All interventions were provided through home visits. In five studies [32, 34, 35, 37, 38], the presence of environmental hazards that could potentially influence falls was assessed. In two studies, modification of the home environment to reduce the fall risk, such as installing a night light path [36] or repairing boilers in a cold home [33], was performed. In four of the five studies in which environmental risk factors were evaluated [32, 35, 37, 38], different scales were used. In the remaining study [34], no scales were used; only examples of home hazards and options to reduce the risk of falling and consequent injuries were presented. In three of the intervention studies [32, 35, 37], older people were given advice or counseling on dealing with the risk factors observed after the evaluation, and in two studies [34, 38], information was provided to enhance knowledge about the causes and prevention of falls related to the home environment (Table 3).

3.4.3. Environmental Risk Factors Considered in the Intervention. Interventions were provided for the bathroom/toilet, bedroom, and living room, which, in nonintervention studies, had been identified as frequent fall locations. In five [32, 33, 35, 37, 38] out of seven studies, interventions were provided for the bathroom; in three studies, for the toilet [35, 37, 38]; and in five studies, for the bedroom [33, 35–38]. When the removal of rugs/carpets was regarded as an intervention for the living room [32], in three studies [32, 35, 37, 38], interventions were provided for the living room. Although the differences in fall location according to general characteristics such as older people's gender [29], age [29], community setting [36], and health status [38] were identified in three nonintervention studies, there were no tailored interventions based on these characteristics.

In five studies, interventions were provided for slipping and tripping, identified as frequent fall situations through nonintervention studies. Interventions for slipping included the improvement of smooth floors/surfaces [37, 38], antislip mats [32, 35, 38], and antislip shoes [34, 38]. Interventions for tripping included the removal of obstacles in walkways such as loose carpet/rug/cord [32, 34, 35, 37, 38] and repair of damaged floors [32, 38] (Table 3).

4. Discussion

Through this comprehensive systematic review, we provide a broad overview of the environmental risk factors for home falls among community-dwelling frail older people. Studies

were included if they measured environmental risk factors or environmental interventions to reduce home falls. Overall, despite the emphasis on the risk of home falls among frail older people, there is a lack of environmental approaches to identify home hazards and improve home safety.

4.1. Needs for Intervention Depending on Home Environment Characteristics. In this systematic review, we investigated the location and identified situations that constituted the main mechanism of home falls. In most studies [32, 35–38], interventions focused on the bathroom/toilet, bedroom, and living room, where falls occur most frequently, and slipping and tripping, which are frequent causes of home falls. In addition, when an intervention including lighting or grab rails, which indirectly contribute to slipping/tripping, was considered, all studies provided interventions for situations in which falls occur frequently. However, although the previous studies [31, 39] have reported differences in fall risk location and situation according to frail older people's community setting, participants' characteristics were not reflected in interventional studies. As the approach to the home environment should be based on regional and/or cultural characteristics [31], it is necessary to link the environmental factors identified in each country with the contents of environmental interventions. The regional and/or cultural characteristics of home environments should be considered when assessing the home falls risk and planning interventions to reduce those risks. For example, through the analysis of nonintervention studies, bathrooms and/or toilets were identified as locations where home falls occurred most frequently [26, 28, 29]. However, in some countries, there is a cultural difference in that the bathroom and toilet are not separate, and the risk of falls may increase owing to slippery floors because toilets are used wet, unlike in other countries where they are used dry [40]. Chen et al. [39] suggested that it may be more effective to reflect regional and/or cultural characteristics when planning interventions to prevent falls in community-dwelling older people. Therefore, it will be helpful to evaluate the home environment of frail older people using an environmental assessment tool that reflects the cultural environment and residential characteristics.

In the US and South Korea, both the evaluation of environmental factors through nonintervention studies and the provision of environmental interventions through intervention studies were conducted. In Gill et al.'s [32] study conducted in the US, interventions were provided to assess and make recommendations regarding participants' home environments. Gill et al. [32] included the removal of loose rugs in the walking path, placement of nonskid mats in the bathroom, repair of walking stairways, and installation of adaptive equipment in bathrooms. These contents of intervention programs seem to reflect the fall risk factors identified in nonintervention studies in the US. However, it is necessary to address the lack of intervention in bedrooms. In Northridge et al.'s [28] nonintervention study conducted in the US, it was identified that first falls occurred in various locations (e.g., bedroom, 25%; dining room, 22%; and kitchen, 8%), whereas later falls were largely confined to the bedroom and that older people who encountered loose grab bars had significantly increased rates of falls compared with those who did not. These results are consistent with those of the previous studies investigating the environmental factors of falls in older people in the US [41, 42]. Moreland et al. [41] found that the most frequent falls in the home occurred in bedrooms, bathrooms, and on the stairs. Therefore, prevention of falls in the bedroom should be emphasized. In Tchalla et al.'s [36] study in France, a night light path was installed in the participants' bedrooms to prevent home falls; significant results were obtained. In the future study, it would be meaningful to confirm the effect of applying such an intervention to the bedrooms of older people in the US.

In a nonintervention study conducted in South Korea, Yoo et al. [31] emphasized that the home environmental safety score of rural-dwelling older people was significantly lower than that of their urban counterparts and that they experienced more falls. Yoo et al. [31] explained that there was a difference in the frequency of falls depending on the floor conditions of the bathroom, kitchen, and living room. In addition, slipping, tripping over obstacles, and false stepping were situations that increased the risk of falls among rural-dwelling older people. Yoo et al.'s [31] findings are consistent with those of the previous studies revealing that slipping was the most common injury mechanism in home falls among older people (81.9%) [43] and that compared to urban houses, rural houses often have thresholds and conventional toilets with slippery floors that are risk factors for falls [44]. In the South Korean intervention study included in this review [38], home environmental safety for rural-dwelling older people was investigated, with the provision of interventions to advance knowledge related to the causes of falls and ways to prevent them in bathrooms, kitchens, living rooms, and bedrooms. However, no specific details were presented regarding interventions that were used to control slipping and tripping, emphasized as fall mechanisms in older people in South Korea. Even within the same country, it is necessary to confirm what kind of environmental hazards exist depending on the community setting; studies should reflect this by providing active interventions, such as removing risk factors and installing assistive devices such as night lights.

Comparative studies should be conducted on community-dwelling frail older people in each country or residential area. These studies are expected to help identify not only home fall risk factors that can be universally applied regardless of the country, residential area, or housing structure but also home fall risk factors that need to be considered specifically according to the residential area and housing structure. It will be helpful to include the home fall risk factors introduced in this review and reflect the cultural environment of each country.

4.2. Multidisciplinary and Multicomponent Approach to Intervention. In only four studies [33–36] that included multidisciplinary interventions, statistically significant effects were observed, confirming the importance of providing

environmental interventions with multidisciplinary teams. As falls are caused by the complex interaction of biological, behavioral, environmental, and socioeconomic risk factors [12], it is important for experts from various disciplines to consider all these factors to identify fall risks. In this study, "multicomponent intervention" refers to an approach other than environmental, such as physical health, physical activity, social functioning, and cognitive functioning. In six of the seven intervention studies, there was a multicomponent intervention, and in one study [35], only environmental interventions were used to prevent home falls. Falls are caused by a combination of individual and environmental factors, and it is known that managing multiple factors is more effective than managing one factor [45]. In most intervention studies in this review, complex interventions were provided. According to the results of a recent systematic literature review on multifactorial interventions for preventing falls among older people, environmental modification is a key component of effective multifactorial fall prevention interventions [45]. Therefore, if multidisciplinary experts cooperate to provide a multicomponent intervention that focuses on environmental intervention as a key element, it will help lower home falls among frail older people. The results of this review reveal that few studies have provided environmental interventions for older people. As the intervention outcomes are different in each study, additional research is needed.

4.3. Need for Participant Engagement and Comprehensive Assessment. Individualized approaches or participation of older people were mentioned in only two [32, 34] of the seven intervention studies. Gill et al. [32] developed detailed algorithms and decision-making rules to assess older people's home environments and link the evaluation results with recommended interventions. The principles of the intervention program included the following: the assessment protocol should be useful in identifying the interventions most relevant for individual participants, and it should be tailored to the combination of comorbidities, contraindications, and personal preferences of a diverse group of frail older people. In addition, after the intervention program, individual compliance was monitored, questions were answered, and encouragement was provided. In another study, Luck et al. [34] provided individualized interventions and recommendations for managing identified risk factors and allowed relatives to participate in the counseling process. In addition, in cases of noncompliance with the recommendations, obstacles and facilitators were assessed, and additional support was provided. In other intervention studies, there were no specific details on how the evaluation results were connected to the intervention and whether the opinions of older people or their families were reflected in the process of providing the intervention. In order to adequately reflect the situation of older people and their families and to provide the desired intervention, investigators studying falls among older people should use standardized definitions to train evaluators and assess environmental hazards. In the process of approaching risk factors in the home environment, the opinions of older people and their families should be reflected.

A comprehensive standardized assessment tool pertaining to the participants' functional and environmental characteristics and needs could be helpful. Using a standardized assessment tool is beneficial not only in integrating the results but also in increasing individuals' participation by exposing the fall risk factors to them [46]. Structured assessment tools raise older people's awareness of fall risk factors in general [46], and community health workers can educate older people about their assessment outcomes and specific circumstances. Environmental interventions for fall prevention should consider each individual's specific situation rather than just environmental control. Furthermore, it is important to provide interventions that can maximize the interaction between the individual and the environment by focusing on the modification of the environment based on the functional limitations of each individual [7, 47, 48].

In seven out of the 14 studies (three noninterventions and four interventions), environmental hazards were assessed using structured tools [27, 28, 31, 32, 35, 37, 38]. These assessment tools were used to evaluate risk factors in the bathroom [28, 31, 32, 37, 38], living room [28, 31, 37, 38], kitchen [31, 37, 38], stairs [31, 37, 38], and bedrooms [28, 37]. The evaluated risk factors included tripping hazards [28, 31, 32, 37, 38] such as carpets, rugs, and clutter; furniture [28, 31, 32, 38] such as beds, chairs, and sofas; storage problems [28, 31, 32, 38] such as the location of storage and the number of storage spaces; bathroom particulars [28, 31, 32, 38] such as grab bar, slip mat, and handrails; floor [31, 32, 37, 38]; shoes [31, 38]; and lighting [32, 37]. A structured assessment of the home environment is a major component of fall prevention strategies [49]. If environmental factors are assessed without using standardized assessment tools, the contents of the environmental factors are so different that it is difficult to integrate the results and plan interventions applicable in practice. Therefore, in future studies, there should be a focus on the locations and situations commonly emphasized as risk factors in the previous studies, and the functional characteristics and needs of the participants for comprehensive assessment should be reflected.

Furthermore, a living laboratory approach, which creates a safe environment to prevent home falls that reflects the risk and needs of the participants based on a comprehensive evaluation, may be helpful. A living laboratory is a physical or virtual space that solves societal challenges by bringing together various stakeholders for collaboration and collective ideation [50]. Through living laboratories, community health workers and policymakers can identify older people's needs, preferences, and expectations. In addition, older people can be aware of their quality of life and the change in perceptions of their own needs and ways of thinking [51].

4.4. Implications for Practice. The locations in the home where most falls occurred were the bathroom/toilet, bedroom, and living room, and the situations were slipping and tripping. The most common intervention was to provide advice or counseling, as well as information to enhance knowledge after visiting the homes of frail older people and

evaluating environmental factors that can affect home falls. Environmental interventions provided by a team of multidisciplinary experts and an active intervention to install lighting in the home were effective. To enhance the effectiveness of intervention programs, when planning an intervention, the home environment should be evaluated considering the functional characteristics and needs of the older people, and factors related to the location and situation wherein most falls occur should be included as major items to be evaluated. Subsequently, it will be effective to provide active interventions by a team of multidisciplinary experts based on the participation of the older people and their family members.

In addition, although assessment of environmental factors and provision of advice and related information through home visits are common, active interventions such as installing devices in homes have rarely been conducted. This may be owing to the upfront costs of environmental modification interventions [52]. However, according to the previous studies, home safety assessment and modification interventions may produce considerable health gains and be cost-effective at the health district level [52]. Targeting environmental interventions to community-dwelling frail older people may be even more cost-effective and the best option to prevent home falls in resource-constrained situations.

In the analysis, all the studies in which the intervention effect was statistically significant were provided by multidisciplinary teams. Frailty is an intrinsic risk factor for home falls, and falls cause additional frailty for older people who are already frail, so a proactive approach is needed to prevent a vicious cycle. A comprehensive, multidisciplinary community health team that can identify environmental and personal risks can lead to effective exploration and mitigation plans that reduce the fall risk. For example, nurses can perform fall risk assessments along with the evaluation of other physiological factors such as cognition, concomitant chronic disease status, and adherence to treatment [53]. Occupational therapists may focus on the condition of footwear, a cluttered home environment, or unsafe furniture arrangements [54]. Social workers may focus on psychological aspects such as problem perception, family support, or availability of community resources [53]. Pharmacists can evaluate the potential effects of drugs on falls and interactions that influence frailty and fall risk factors.

4.5. Limitations and Future Research. This review has some limitations. Few studies entail environmental interventions for frail older people, and there is considerable heterogeneity in the definition of this population and the environmental approaches in the literature included in the analysis. In future research, standardized tools should be used to include frail older people and evaluate the home environment to draw integrated conclusions.

In addition, in most intervention studies, environmental risk factor assessment and environmental modification were only one part of a multicomponent intervention and the contents of the environmental intervention were only partially presented. Future studies should make more active use of designs for evaluating multicomponent interventions. One way to accomplish this would be to divide the evaluation into three groups as follows: provided only as environmental intervention, provided only as individual intervention such as exercise intervention, and provided as both environmental and individual intervention. If the effect of each component is checked by dividing it into each group, it will be possible to provide more complete information on detailed evaluation and modification of groups focusing on environmental approaches.

5. Conclusion

The home environment is increasingly being emphasized as a key factor in home falls among frail older people. In this systematic review, we identified the environmental risk factors associated with home falls in community-dwelling frail older people and confirmed how such findings can be applied to interventions. Through a review of non-interventional studies, it was confirmed that the most risky location for home falls among frail older people living in the community was the bathroom/toilet and the most risky situation was slipping/tripping. These risk factors were dealt with relatively well in the intervention studies. However, because home falls are influenced by regional factors, such as cultural background and house characteristics, it is necessary to assess environmental risk factors for each community setting and provide interventions that take into account the residences of older people. In addition, comprehensive standardized environmental evaluations should be conducted considering the functional characteristics and needs of the older people, with their participation in the intervention process.

Data Availability

The data supporting this systematic review are from previously reported studies and datasets, which have been cited. The processed data are available frome the reference section [24–37].

Additional Points

What is known about this topic? (i) Falls seriously affect the health of older people. (ii) Frail older people are exposed to indoor environmental risks, and nonfrail older people are exposed to outdoor environmental risks. (iii) Environmental interventions can help reduce home falls in community-dwelling frail older people What this paper adds? (i) Nonintervention studies showed that the bathroom/toilet was the location with the highest risk of home falls. (ii) Intervention studies included locations and situations that nonintervention studies had identified as a high fall risk as environmental factors. (iii) The most common interventions entailed information provision and environmental risk evaluation, and a few studies included practical modifications of the home environment based on

participants' situations. (iv) All studies where the intervention effect was statistically significant were conducted by multidisciplinary teams.

Ethical Approval

Ethical approvals were sought by the individual studies. No additional approval was required for this systematic review.

Disclosure

The protocol of this systematic review was registered online with PROSPERO, the International Prospective Register of Systematic Reviews (CRD42021284097). We planned a meta-analysis, but the number of studies was insufficient, and various study designs and methods were used in the literature. In addition, as a solely environmental intervention was provided in only one of seven studies, with multicomponent interventions provided in the other six consisting of different contents, we could not achieve integrated results regarding the effects of environmental intervention. Therefore, we divided the studies of various designs into intervention and nonintervention studies and confirmed the relevance of the environmental risk factors identified in the nonintervention studies and considered in the intervention studies.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

NK, MSS, and GSK conceptualized and designed the study; MKP, NK, MSH, and JJL performed data acquisition; MKP, NK, JJL, and GSK performed analysis and interpretation of data; MKP performed drafting of the article; and all the authors revised it critically for important intellectual content and approved the final version of the manuscript.

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Supplementary Materials

Supplemental Material 1: this supplementary material includes the search strategies and the search results obtained from each database. Supplemental Material 2: this supplementary material provides detailed information on the specific criteria used for the MMAT and presents the quality assessment results for each study. (*Supplementary Materials*)

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