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Interventions to Prevent Falls in Older Adults
Updated Evidence Report and Systematic Review for the US Preventive Services Task Force

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IMPORTANCE Falls are the most common cause of injury-related morbidity and mortality among older adults.

OBJECTIVE To systematically review literature on the effectiveness and harms of fall prevention interventions in community-dwelling older adults to inform the US Preventive Services Task Force.

DATA SOURCES MEDLINE, PubMed, Cumulative Index for Nursing and Allied Health Literature, and Cochrane Central Register of Controlled Trials for relevant English-language literature published through August 2016, with ongoing surveillance through February 7, 2018.

STUDY SELECTION Randomized clinical trials of interventions to prevent falls in community-dwelling adults 65 years and older.

DATA EXTRACTION AND SYNTHESIS Independent critical appraisal and data abstraction by 2 reviewers. Random-effects meta-analyses using the method of DerSimonian and Laird.

MAIN OUTCOMES AND MEASURES Number of falls (number of unexpected events in which a person comes to rest on the ground, floor, or lower level), people experiencing 1 or more falls, injurious falls, people experiencing injurious falls, fractures, people experiencing fractures, mortality, hospitalizations, institutionalizations, changes in disability, and treatment harms.

RESULTS Sixty-two randomized clinical trials (N = 35 058) examining 7 fall prevention intervention types were identified. This article focused on the 3 most commonly studied intervention types: multifactorial (customized interventions based on initial comprehensive individualized falls risk assessment) (26 trials [n = 15 506]), exercise (21 trials [n = 7297]), and vitamin D supplementation (7 trials [n = 7531]). Multifactorial intervention trials were associated with a reduction in falls (incidence rate ratio [IRR], 0.79 [95% CI, 0.68-0.91]) but were not associated with a reduction in other fall-related morbidity and mortality outcomes. Exercise trials were associated with statistically significant reductions in people experiencing a fall (relative risk, 0.89 [95% 13 CI, 0.81-0.97]) and injurious falls (IRR, 0.81 [95% CI, 0.73-0.90]) and with a statistically nonsignificant reduction in falls (IRR, 0.87 [95% CI, 0.75-1.00]) but showed no association with mortality. Few exercise trials reported fall-related fractures. Seven heterogeneous trials of vitamin D formulations (with or without calcium) showed mixed results. One trial of annual high-dose cholecalciferol (500 000 IU), which has not been replicated, showed an increase in falls, people experiencing a fall, and injuries, while 1 trial of calcitriol showed a reduction in falls and people experiencing a fall; the remaining 5 trials showed no significant difference in falls, people experiencing a fall, or injuries. Harms of multifactorial and exercise trials were rarely reported but generally included minor musculoskeletal injuries.

CONCLUSIONS AND RELEVANCE Multifactorial and exercise interventions were associated with fall-related benefit, but evidence was most consistent across multiple fall-related outcomes for exercise. Vitamin D supplementation interventions had mixed results, with a high dose being associated with higher rates of fall-related outcomes.

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Falls are the leading cause of injury-related morbidity and mortality among older adults in the United States.[1] In 2014, 28.7% of community-dwelling adults 65 years and older reported falling, resulting in 29 million falls (37.5% of which necessitated medical treatment or restricted activity for a day or longer),[2] and there were an estimated 33 000 fall-related deaths in 2015.[1]

Given this large burden of morbidity and the complexity of falls in older adults, it is important to determine which fall prevention interventions targeting modifiable fall risk factors (eg, balance and gait abnormalities, environmental factors, medication adverse effects) are effective. Fall prevention interventions relevant for primary care populations can include exercise, medication review, dietary supplements (eg, vitamin D), environment modifications, and behavioral therapy. These interventions can be delivered alone or in combination with or without intervention customization based on an initial comprehensive patient assessment (ie, multifactorial or multiple interventions).

In 2012, the US Preventive Services Task Force (USPSTF) recommended 2 types of interventions—exercise and vitamin D supplementation—to prevent falls in older adults at increased risk for falls (B recommendation). Depending on individual patient preferences and circumstances, multifactorial interventions were selectively recommended (C recommendation).[3] The USPSTF commissioned this systematic review to inform their updated recommendation for fall prevention in older adults. The aim was to determine which fall prevention interventions reduce falls, falls-related morbidity, and all-cause mortality and any associated adverse effects of these interventions.

Methods

Scope of Review

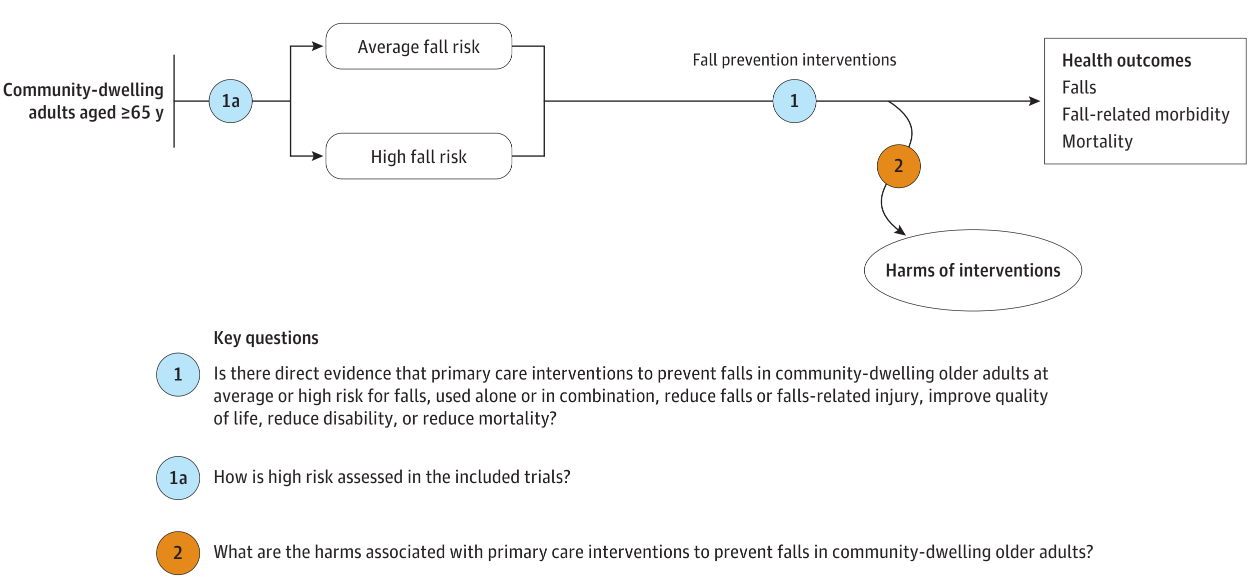
An analytic framework was developed with 2 key questions (KQs) (**Figure 1**) that examined the effect of fall-prevention interventions on health outcomes (KQ1) and the harms of these interventions (KQ2). A draft of the analytic framework, review questions, and inclusion and exclusion criteria was posted on the USPSTF website from August 6, 2015, to September 2, 2015, to gather public input. Minor changes were made to the inclusion and exclusion criteria to clarify the included populations, interventions, and settings. No major changes were made to the scope of the review or the approach to synthesizing the evidence. Detailed methods and results are reported in the full evidence review at https://www.uspreventiveservicestaskforce.org/Page/Document/UpdateSummaryFinal/falls-prevention-in-older-adults-interventions1. Findings for other interventions (medication management, environment modification, psychological interventions, and multiple interventions) are available in the full report.

Data Sources and Searches

MEDLINE, PubMed (publisher-supplied references only), Cumulative Index for Nursing and Allied Health Literature, and Cochrane Central Register of Controlled Trials were searched from January 1, 2010, to August 30, 2016, and supplemented by checking reference lists from the prior 2010 review for the USPSTF[4] and another relevant systematic review[5] (eMethods in the Supplement). ClinicalTrials.gov and the WHO International Clinical Trials Registry Platform were searched for ongoing trials. Since August 30, 2016, ongoing surveillance through article alerts and targeted searches of journals with a high impact factor and journals relevant to the topic was conducted to identify major studies published in the interim that may affect the conclusions or understanding of the evidence and therefore the related USPSTF recommendation. The last surveillance was conducted on February 7, 2018.

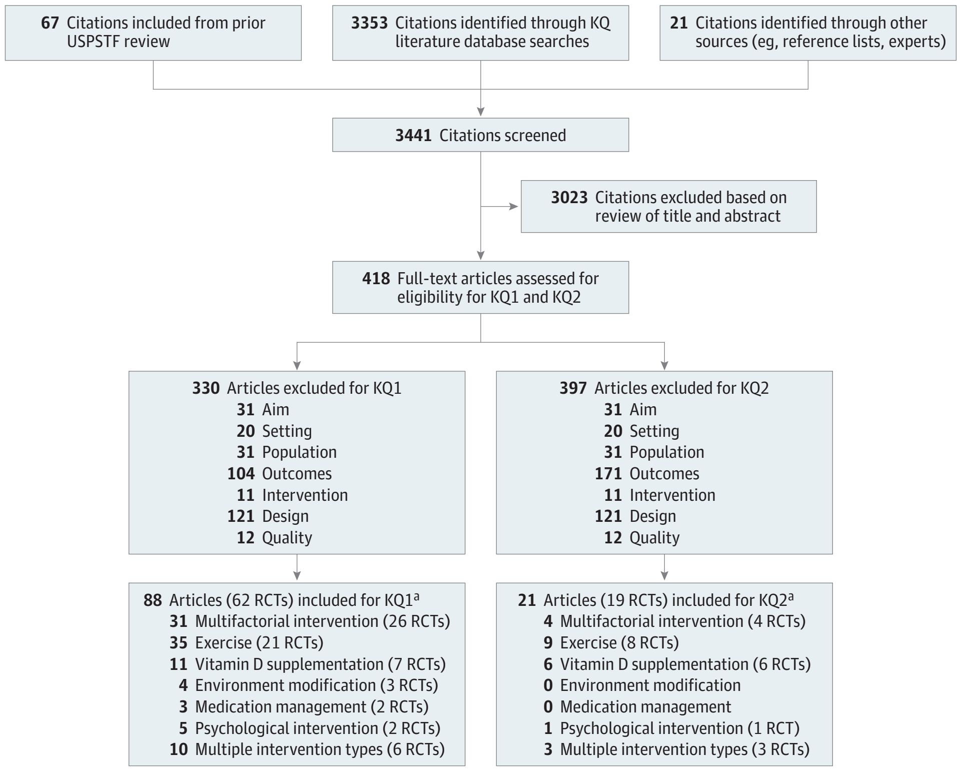
After the surveillance scan and checking the reference list from a network meta-analysis,[6] 2 relevant studies were identified that met the inclusion criteria but did not change the conclusions: 1 multifactorial intervention[7] and 1 environment modification intervention trial.[8]

Figure 1. Analytic Framework



Evidence reviews for the US Preventive Services Task Force (USPSTF) use an analytic framework to visually display the key questions that the review will address to allow the USPSTF to evaluate the effectiveness and safety of a preventive service. The questions are depicted by linkages that relate interventions and outcomes. Refer to the USPSTF Procedure Manual for further details.[10]

Figure 2. Literature Search Flow Diagram



[a] Trials may be included in more than 1 intervention type.

Study Selection

Two reviewers independently reviewed 3441 unique citations and 418 full-text articles against a priori inclusion criteria (**Figure 2**; eTable 1 in the Supplement). Randomized clinical trials (RCTs) and cluster RCTs of community-dwelling older adults (≥65 years), including those at average or high risk for falls (high risk as defined by the study authors) were included if they had a primary or secondary aim of preventing falls or a related aim (eg, fear of falling). Fall prevention interventions that are feasible in the primary care setting or referable from primary care were included.

The intervention types were based on taxonomy developed by researchers from the Prevention of Falls Network Europe (ProFaNE) group.[9] Many intervention types were included: exercise, vitamin D supplementation, environment modifications, psychological interventions, medication management, and knowledge and education. These intervention types could be delivered alone (ie, single), in combination (ie, multiple), or as a customized combination of interventions determined from the results of an individual baseline assessment (ie, multifactorial). Falls (number of unexpected events in which a person comes to rest on the ground, floor, or lower level) or fallers (number of people experiencing 1 or more falls) were the most commonly reported fall-related outcomes in the trials. Trials measuring self-reported falls, with a recall of 6 months or less as a primary or secondary outcome, were included.

Trials solely recruiting participants with specific medical diagnoses (eg, neurologic diagnoses such as dementia, Parkinson disease, or stroke) were excluded because those populations may require specialized approaches to preventing falls. Trials solely recruiting participants with vitamin D insufficiency or deficiency, as determined by the study authors, were excluded. A sensitivity analysis was performed combining the included vitamin D trials and the trials excluded for their vitamin D deficiency or insufficiency criteria. Certain intervention types (surgery, fluid or nutrition therapy, management of urinary incontinence, optical aids, hearing aids, body-worn protective aids) were excluded unless they were one possible component of multifactorial interventions. All harms were restricted to those identified in studies included for intervention effectiveness, with the exception of medications and supplements. For the harms of vitamin D, systematic reviews were additionally included.

The full evidence review reports on any included intervention types for which published studies were found, but this article focuses on 3 intervention types: multifactorial, exercise, and vitamin D supplementation. The remaining 4 intervention types (environment, psychological, medication management, multiple) had limited data, and results for those intervention types are available in the full evidence report.

Data Extraction and Quality Assessment

Included trials were critically appraised by 2 independent reviewers using predefined criteria,[10] with disagreements resolved by a third reviewer (eTable 2 in the Supplement). One reviewer abstracted descriptive and outcome data from each included study into standardized evidence tables; a second checked for accuracy and completeness.

Data Synthesis and Analysis

Data were qualitatively and quantitatively synthesized. A random-effects meta-analysis using the method of DerSimonian and Laird[11] was used to calculate the pooled relative risks (RRs) when there was a sufficient number of contributing studies reporting an outcome for a given intervention type and outcome. Within each study, the longest follow-up available was used for pooled analyses and figures. For intervention types and outcomes that did not allow for quantitative pooling because of the limited number of contributing studies, those data are summarized narratively and qualitative synthesis was performed. In studies with several groups, the most intensive intervention and 1 control group for each intervention type were abstracted and included in the analysis.

There were 12 KQ1 outcomes for which data were abstracted. This manuscript focuses on the most widely reported outcomes: falls, injurious falls, fractures, people experiencing a fall, people experiencing an injurious fall, people experiencing a fracture, and mortality. The remaining outcomes (people transitioning to institutionalized care, people hospitalized, quality of life, activities of daily living, and instrumental activities of daily living) are available in the full evidence report. For a composite injurious fall outcome, any minor or severe injuries resulting from a fall, falls resulting in medical care, or any fall-related outcome the author categorized as injurious was accepted. The meta-analysis of injurious falls included both the number of fall-related injuries and the number of falls resulting in injury as reported in the trials. For fracture outcomes, fall-related fractures was used preferentially in the meta-analysis, but if that outcome was not available, data on hip fractures and overall fractures were used, even if the study may not have reported if the fracture was associated with a fall.

In cases in which a cluster RCT was used but the authors did not account for the nested nature of the data, adjustment was made for the clustering effect by applying a design effect, which was based on an estimated mean cluster size (the total number of randomized participants divided by the total number of clusters) and multiplied by an estimated intraclass correlation.[12]

Statistical heterogeneity was examined among the pooled studies using standard χ^2 tests, and the proportion of total variability in point estimates was estimated using the I^2 statistic.[13]

After results were pooled, investigation of heterogeneity between trials for falls and people experiencing a fall was performed by examining variability by any prespecified population or intervention characteristics of the studies. First, visual displays and tables were grouped or sorted by these potentially important characteristics. Specifically, variables included recruitment setting (emergency department, clinic, or a combination), mean age, percentage female, risk of falls (high or average risk, as defined by the authors), fall rate of the control group or the percent falling, country (United States vs others), and study quality (fair vs good) as they related to the effect estimates. Because age and other individual and environmental factors determine risk of fall, control group fall rates were calculated as an indicator of fall risk status in addition to individual trials' definitions of "high risk." For exercise interventions, additional variables included duration and intensity, presence of exercise components (eg, balance, flexibility, strength), number of components, supervision, and format (group, individual, or both). Based on visual examination of forest plots, meta-regression was used to test for potentially significant sorting variables or groups, namely the recruitment setting for the falls outcome for multifactorial interventions.

Stata version 13.1 (Stata Corp LP) was used for all quantitative analyses. All significance testing was 2-sided. Results were considered statistically significant if the $P < .05$.

Results

Benefits of Interventions

Key Question 1. Is there direct evidence that primary care interventions to prevent falls in community-dwelling older adults at average or high risk for falls, used alone or in combination, reduce falls or falls-related injury, improve quality of life, reduce disability, or reduce mortality?

Key Question 1a. How is high risk assessed in the included trials?

Sixty-two trials (published in 88 articles) (N = 35 058) met the inclusion criteria for this systematic review (Figure 2). This article focuses on the 3 most common intervention types, with 26 trials of multifactorial,[14-39] 21 of exercise,[40-60] and 7 of vitamin D supplementation interventions.[48,61-66] Thirteen trials were included for other intervention types; these are not discussed further here and are available in the full evidence report.

Multifactorial Interventions

Study and Population Characteristics

Seven good-quality[21,23,25,27,30,32,35] and 19 fair-quality RCTs[14-20,22,24,26,28,29,31,33,34,36-39] (n = 15 506) with a primary or secondary aim of examining the effectiveness of multifactorial interventions on falls, fall-related injuries, or both at 6 to 36 months of follow-up were identified (eTable 3 in the Supplement). The majority of the trials were conducted in Europe, with trial size ranging from 100 to 5 310 participants. The mean age ranged from 72 to 85 years, and the percentage of women ranged from 53% to 94%.

High-Risk Definition

The most common risk factor used for recruitment was history of falls. Seven trials recruited patients at average risk of falling, in which the only risk factor for falls was age.[21,22,28,29,33,34,38] Of the 26 studies, 12 defined high risk as having a history of falling based on either historical recall of 1 or more falls in the previous 3 months[17] or 12 months,[19,23,24] or seeking medical attention in an emergency department, hospital, ambulance, or clinic after a fall.[15,16,18,20,27,31,35,39] The remainder of the trials recruited participants who fulfilled 1 or more risk factor criteria from a list of possible risk factors (eTable 3 in the Supplement).

Intervention Details

The intervention groups received an initial comprehensive geriatric assessment or a falls risk factor assessment, followed by customized treatment interventions and referrals managed by the research team. This initial comprehensive geriatric assessment included any number of the following components: balance, gait, vision, cardiovascular health (eg, postural blood pressure or pulse, carotid sinus stimulation), medication, environment (eg, home hazards or personal needs), cognition, and psychological health. Nursing professionals nearly always performed the initial assessment, with or without additional professionals (eg, physical therapists, exercise instructors, occupational therapists, medical doctors, dieticians, or nutritionists).

The treatment interventions varied substantially across the studies but generally included multiple targeted intervention components, such as exercise (unsupervised or supervised, group or individual); psychological (cognitive behavioral therapy); nutrition therapy; knowledge (eg, via DVDs, lectures, pamphlets); medication management; urinary incontinence management; environment modifications (eg, assistive technology or dwelling recommendations); and referral to physical or occupational therapy, social or community services, and specialists (eg, ophthalmologist, neurologist, cardiologist).

In most (22/26) of the trials, treatment interventions were implemented through a combination of direct treatment administered by the research team as well as specialty referrals generated by the research team. In more than half (14/26) of the trials, the research team also communicated with primary care physicians, generally to communicate specific or comprehensive risk-assessment results.[14,15,17-19,23-25,28,31,33,35,37,38]

Total contact time was rarely reported. Most trials reported that they directly offered or referred participants to a supervised single or serial session exercise intervention. This offer was often targeted to participants with balance or gait issues identified in the risk assessment.

Control groups in the trials received usual care or usual care plus minimal control (pamphlet, social visit, brief falls risk advice, letter).[17,19,23,25,37-39]

Intervention Effects on Morbidity and Mortality

Multifactorial interventions were associated with a reduced incidence in the rate of falls, with substantial heterogeneity (17 trials [n = 9737]; incidence rate ratio [IRR], 0.79 [95% CI, 0.68-0.91]; P = .001; I^2 = 87.2%; median decrease of 1.5 events per person-year between intervention group and control group) (eFigure 1 in the Supplement). Control group rate of falls per person-year ranged from 0.38 to 7.7 events per person-year at the longest follow-up, indicating a wide variation in baseline fall risk among the included trials. Individual trials reported substantial variation in effect size, with wide and overlapping CIs and with IRR point estimates ranging from 0.42 to 1.12. Pooled analyses showed no statistically significant association between multifactorial interventions and people experiencing a fall (24 trials [n = 12 490]; RR, 0.95 [95% CI, 0.89-1.01]; P = .09; I^2 = 56.4%) (eFigure 2 in the Supplement), people experiencing an injurious fall (16 trials [n = 9445]; RR, 0.94 [95% CI, 0.85-1.03]; P = .18; I^2 = 34.3%) (eFigure 3 in the Supplement), or mortality (23 trials [n = 9721]; RR, 0.96 [95% CI, 0.79-1.17]; P = .66; I^2 = 0.0%) (eFigure 4 in the Supplement). The heterogeneity was not explained by any single variable except recruitment setting (eFigure 5 in the Supplement).

In meta-regression, both clinical and multiple recruitment settings were statistically different than that of the emergency department (P = .03 and P = .02, respectively), suggesting that studies recruiting from emergency settings were associated with a higher reduction in falls. Caution should be used in interpreting this post hoc subanalysis because heterogeneity was high and formal a priori subgroup credibility ratings were not performed.[10]

For other outcomes including injurious falls, fracture, persons with a fracture, disability, quality of life, people hospitalized, and people who transitioned to institutional care, the few identified studies were underpowered and revealed no consistent effect of the multifactorial intervention (details available in the full evidence report).

Exercise Interventions

Study and Population Characteristics

Five good-quality[47,48,54,55,60] and 16 fair-quality[40-46,49-53,56-59] RCTs (n = 7297) with a primary or secondary aim of examining the effectiveness of exercise on reducing falls, fall-related injuries, or both at 6 to 60 months of follow-up were identified. The majority of trials were conducted in Europe, with number of trial participants ranging from 55 to 1635. The mean age ranged from 68 to 88 years, and in all but 1 trial the majority or all participants were women.

High-Risk Definition

Twelve trials recruited participants at high risk for falls,[42-44,46,48,50,52,53,55,56,58,60] using a variety of risk factor criteria (eTable 3 in the Supplement). The most common risk factor used for recruitment, alone or in combination with other risk factors, was limitation of physical function or mobility (self-reported or objectively measured).

Intervention Details

Mean duration of the exercise interventions was approximately 12 months, and the most common frequency was 3 exercise sessions per week. The exercise interventions varied by the type and number of exercise components included and whether the exercise was conducted primarily alone or as a group. The most common type of exercise component was gait, balance, and functional training (classified using the ProFaNE taxonomy[9]); 17 of the 21 trials used this component alone[46,50,52,56,57] or in combination with another type of exercise.[41,42,44,45,48,49,53-55,58-60] Seven of the trials included group exercise,[40,46,47,49,54-56] 9 evaluated group exercises in addition to home-based individual exercises,[42-44,48,50,53,57,58,60] and 5 evaluated individually based exercise only.[41,45,51,52,59] Most of the control groups in the trials were instructed to maintain usual activity levels or usual activity plus minimal control (pamphlet, social visit, brief falls risk advice).

Intervention Effects on Morbidity and Mortality

These 21 exercise trials (n = 7297) with varying baseline fall risk (ranging from 0.04 to 1.6 falls per person-year in control groups) showed reductions in falls outcomes. In pooled analyses, exercise interventions were associated with a reduced risk of falling (15 trials [n = 4926]; RR, 0.89 [95% CI, 0.81-0.97]; P = .01; I^2 = 43.9%), with a median absolute decrease in participants falling of 3.8 percentage points (eFigure 6 in the Supplement) and a reduced rate of injurious falls (10 trials [n = 4622]; IRR, 0.81 [95% CI, 0.73-0.90]; I^2 = 0.0%), with a median decrease of 0.35 falls per person-year (eFigure 7 in the Supplement). There was no statistically significant association between exercise interventions and a reduced rate of incident falls (14 trials [n = 4663]; IRR, 0.87 [95% CI, 0.75-1.00]; P = .05; I^2 = 57.3%) (eFigure 8 in the Supplement). The high heterogeneity did not appear to be associated with any of the prespecified population or intervention characteristics of the studies.

Fall-related fractures and injurious falls were not widely reported in the included trials, and while trials that did report those outcomes showed a reduction in rates, those reductions were not consistently statistically significant. Three trials (n = 2047) that evaluated fractures showed a reduced rate of fall-related fractures, with IRR estimates ranging from 0.26 to 0.92, and 5 trials (n = 2776) that evaluated risk of injurious falls showed a reduced risk, with IRR estimates ranging from 0.61 to 0.90. Pooled analyses showed no statistically significant association between exercise interventions and mortality (11 trials [n = 4263]; RR, 0.93 [95% CI, 0.71-1.22]; $P = .60$; $I^2 = 0.0\%$) (eFigure 9 in the Supplement).

For other outcomes, the few identified studies were underpowered and revealed no consistent effect of exercise interventions (details available in the full evidence report).

Vitamin D Interventions

Study and Population Characteristics

Four good-quality[48,64-66] and 3 fair-quality[61-63] RCTs (n = 7531) with a primary or secondary aim of examining the effectiveness of vitamin D supplementation on falls, fall-related injuries, or both at 9 to 60 months of follow-up were identified. Five trials were conducted in Europe or Australia, and trial sizes ranged from 204 to 3314 participants. Mean age ranged from 71 to 77 years, and 5 of the 7 studies were conducted exclusively in postmenopausal women.

High-Risk Definition

Three trials recruited only patients at high risk (based on varying definitions) for falls.[48,63,66] One study defined high risk as a history of falls in the previous 12 months,[48] and the 2 remaining studies[63,66] defined high risk as the presence of 1 or more risk factors, including maternal or family history of hip fracture,[63,66] self-reported fall,[66] previous fracture,[63,66] low body weight (<58 kg),[63] or self-reported health that was fair or poor.[63]

Baseline mean serum 25-hydroxyvitamin D levels in the study populations were reflective of mean vitamin D levels in adults 60 years and older in the United States,[67] ranging from 26.4 ng/mL (65.9 nmol/L)[65] to 31.8 ng/mL (79.4 nmol/L).[62] While 1 Australian trial reported lower serum levels, with a median of 21 ng/mL (52.4 nmol/L) in the intervention group and 18 ng/mL (44.9 nmol/L) in the control group, these levels were reflective of normative vitamin D levels in Australia.[66]

Intervention Details

Vitamin D_3 was administered orally in all studies with various formulations, including cholecalciferol,[48,63-66] 1-hydroxycholecalciferol,[61] and calcitriol.[62] The dosing schedules varied; the cholecalciferol trials used a dose of 700 IU daily,[64] 800 IU daily,[48,63] 150 000 IU every 3 months,[65] or 500 000 IU annually.[66] The other 2 trials administered 1 μg of 1-hydroxycholecalciferol daily[61] and 0.25 μg of calcitriol twice daily.[62] In 2 studies, the intervention group received calcium (500 mg/d[64] or 1000 mg/d[63]) in addition to vitamin D. Vitamin D was administered for 9 months up to 5 years. The control groups received a matched placebo in 6 of the 7 trials,[48,61,62,64-66] and 1 study was open-label.[63]

Intervention Effects on Morbidity and Mortality

These 7 heterogeneous trials (n = 7531) of different vitamin D_3 formulations and dosing schedules in older adults with varying baseline fall risk (ranging from 0.37 to 1.18 falls per person-year in control groups) showed mixed results. The single trial of annual high-dose cholecalciferol (500 000 IU) showed an increase in falls, people experiencing a fall, and injurious falls[66]; the trial of calcitriol showed a reduction in falls and people experiencing a fall,[62] and the remaining studies showed no statistically significant difference in falls, people experiencing a fall, or injurious falls.[48,61,63-65] Pooled results showed no statistically significant association between vitamin D supplementation and falls (5 trials [n = 3529]; IRR, 0.97 [95% CI, 0.79-1.20]; $I^2 = 75.8\%$) (eFigure 10 in the Supplement), people experiencing a fall (6 trials [n = 6519]; RR, 0.97 [95% CI, 0.88-1.08]; $I^2 = 60.3\%$) (eFigure 11 in the Supplement), or mortality (6 trials [n = 7084]; RR, 1.08 [95% CI, 0.83-1.40]; $I^2 = 0.0\%$) (eFigure 12 in the Supplement). Sensitivity analysis removing the high-dose annual vitamin D trial showed no statistically significant association between vitamin D and falls (IRR, 0.91 [95% CI, 0.68-1.22]) (eFigure 13 in the Supplement).

An additional sensitivity analysis adding trials excluded from the review because they recruited participants with vitamin D insufficiency or deficiency did not show a statistically significant association with people experiencing a fall (RR, 0.88 [95% CI, 0.78-1.00]).

Incident fractures and quality of life were rarely reported, and no studies reported disability. Mixed results were found for the association of vitamin D and people with fractures (details available in the full evidence report).

Harms of Interventions

Key Question 2. What are the harms associated with primary care interventions to prevent falls in community-dwelling older adults?

Four of 26 multifactorial trials reported information on harms (n = 1466).[18,23,25,32] Only 1 of these trials reported harms (back pain) in the control group for comparison, which showed no difference between the intervention and control groups.[32] One trial reported 3 falls without injury during the exercise component of the intervention.[23] In general, harms were rare, minor, and associated with the exercise component of the multifactorial intervention.

Eight of 21 exercise trials (n = 4107) reported harms in the intervention group.[48,49,52,53,55,56,58,60] Two of these trials also reported harms in the control group for comparison and reported no difference in the rate of serious injuries between the intervention and control groups.[53,60] In general, harms reported for these exercise interventions were minor and included pain, bruising, or fall injuries or fractures that occurred during the exercise sessions.

Five of 7 vitamin D supplementation trials (n = 3955) reported information on harms associated with vitamin D and showed no difference in the frequency of harms attributable to treatment.[61,62,64-66] As noted above, 1 trial reported an increase in falls, people experiencing a fall, and fall-related injuries associated with the annual high dose (500 000 IU) of cholecalciferol. The event rates for several of the reported harms that did occur (eg, kidney stones, diabetes) indicated that these were rare. Transient hypercalcemia was reported in 2 trials[61,62] and was described as mild or clinically asymptomatic; a single case of hypercalciuria was reported in the treatment group in 1 trial.[64,68] Most of the adverse effects reported are unlikely to be attributable to vitamin D.

Discussion

The summary of evidence for this review is shown in the Table. These findings suggest that multifactorial and exercise interventions are associated with a reduction in fall outcomes. The evidence on the association between vitamin D supplementation and fall outcomes, however, is inconsistent. Although the evidence showed that multifactorial and exercise interventions were both associated with fewer falls, evidence for exercise is more consistent across multiple fall-related outcomes. Multifactorial interventions, which include risk-based, customized referrals and treatments, appear to reduce falls but not people experiencing a fall or injuries. This may be attributable, at least in part, to limited study power. While there are numerous multifactorial trials designed with somewhat similar strategies, the studies are clinically and statistically heterogeneous and, as such, drawing conclusions regarding elements of effective multifactorial interventions from this body of literature is difficult. Exercise interventions are associated with fewer people experiencing a fall, injurious falls, and people experiencing an injurious fall in average- and high-risk community-dwelling older adults. No specific effective exercise or multifactorial protocol has been replicated in larger population randomized clinical trials. The results on effectiveness of vitamin D supplementation were mixed and showed potential harm at very high doses.

Similar to the conclusions of this review, a recent network meta-analysis,[6] which included both community-dwelling and institutionalized older adults, found that exercise alone was associated with fewer people experiencing a fall and fewer injurious falls. Other statistically significant intervention combinations associated with fewer people experiencing a fall and fewer injurious falls compared with usual care included combined exercise, clinic-level quality-improvement strategies, multifactorial assessment and treatment, calcium supplementation, and vitamin D supplementation interventions.

This review represents an update to the 2010 systematic review for the USPSTF,[4,69] with a few notable differences. Unlike the previous review, the updated findings do not support an association between vitamin D supplementation and reduced falls in the general population of older adults. The exclusion in this review of studies recruiting populations with vitamin D deficiency or insufficiency resulted in a mixed picture from fewer included trials. The conclusions regarding the association of multifactorial and exercise interventions with a reduction in falls or fallers are similar between this review and the prior USPSTF review.

Other researchers have reported conflicting results on the effect of vitamin D supplementation on falls.[70,71] Some systematic reviews that included trials recruiting institutionalized participants and those with vitamin D deficiency or insufficiency reported a pooled reduction in falls or fractures, but the dose and target population remain uncertain.[6,72-74] Other authors have concluded from the broader literature on vitamin D (including vitamin D–deficient or –insufficient populations) that vitamin D supplementation, with or without calcium, does not reduce falls among older adults[5,75] and that new studies are unlikely to change this conclusion.[76]

Ideally, effective interventions would not only reduce falls but also result in reductions in fractures and other fall-induced injuries. Consistent with findings from other systematic reviews,[6,77] exercise interventions included in this review were associated with fewer injurious falls. For multifactorial interventions, while evidence for their effect on injuries or fracture was either too limited to make conclusions or the available evidence suggests no effect, concluding that interventions other than exercise have no effect on injuries would be premature, given that so few of the trials were designed to have adequate power for preventing injury or fracture.[37,39,50,63,66] To increase the power to analyze the effect of interventions on injuries, a composite category of "injurious falls" was created in this review; however, the severity of injuries may vary widely, even among falls that lead to emergency department visits. The effect of the included interventions on injuries including fractures showed inconsistent and imprecise results. The certainty of the effects of fall prevention interventions on fracture is low because these outcomes were only reported in a minority of the included trials.

In the included studies, while the majority of trials were conducted in populations with a high risk of falls, the approaches to identifying high-risk patients varied. The most common approach used to identify a person at high risk of falls was collecting the patient's history of falls. The remaining trials conducted with high-risk populations evaluated 2 or more risk factors (eg, history of a fall, difficulty with mobility, use of health care) and included participants with any of these risk factors.

In practice, clinicians are challenged in selecting high-risk patients for fall prevention interventions by a lack of evidence to support effective tools for assessing risk of falls. For any given tool, use of different cutpoints to indicate high risk makes it difficult to compare likelihood ratios across the available studies. Systematic reviews of the Timed Up and Go test and other clinical screening tests for the risk of falls suggest that evidence of the adequacy of these screening instruments for predicting falls is insufficient.[78,79] A 2016 systematic review of tools for assessing risk of falls concluded that no single test or measure included in the review (56 measures including history questions, self-report measures, and performance-based measures) was an accurate diagnostic tool.[80]

Given the complex set of factors contributing to falls in older individuals, combining measures may help to accurately predict future falls; however, such combinations have not been validated in large studies. Evidence did not suggest that trials targeting populations at high risk of falls (other than recruitment from emergency settings in the multifactorial intervention studies) were more effective in reducing falls compared with trials of populations at average risk of falls.

There are several important considerations when applying these findings for multifactorial and exercise interventions to US primary care. Interventions in the multifactorial trials, including physician specialty referrals, exercise interventions, and environmental interventions, are reflective of what patients could receive individually in the current US health care delivery system, although rarely in such a comprehensive fashion. The exercise interventions included in these multifactorial trials were similar to what patients receive in the US clinical setting in their design, delivery, and components. The interventions offered in the included exercise trials are different from typical physical therapy referrals available in the US clinical setting in their design and delivery. Most of these exercise trials are similar to intensive programs available in the community setting but not the clinical setting.

Table. Summary of Evidence

Intervention Type, No. of Studies (No. of Participants Randomized) Study Quality	Outcome	No. of RCTs (No. of Observations)	Summary of Findings by Outcome	Consistency and Precision	Reporting Bias	EPC Assessment of Strength of Evidence	Body of Evidence Limitations	Applicability
Key Question 1. Benefits Associated With Primary Care Interventions to Prevent Falls in Community-Dwelling Older Adults; Assessment of Risk in the Included Trials								
Multifactorial 26 Studies (n = 15 506) 7 Good quality, 19 fair quality	Falls	17 (n = 9737)	Pooled analysis shows associated reduction in falls (IRR, 0.79 [95% CI, 0.68-0.91]; I^2 = 87.2%) with substantial heterogeneity. Exploratory analysis suggests that trials recruiting from emergency setting report greater benefit (vs trials recruiting from clinic or a combination of clinic and emergency setting).	Inconsistent, imprecise	Undetected	Low	Heterogeneous populations as reflected by large variation in control group fall rate and percentage of fallers. Heterogeneous group of interventions. Cannot make conclusions about which components associated with greater falls-related benefit. Most studies report and designed to be powered for either falls or fallers outcomes.	Applicable to community-dwelling older adults. Three-fourths of trials in "high-risk" older adults, where high risk is variably defined but often includes history of fall. Difficult to identify set of effective components for implementation purposes.
	People experiencing a fall	24 (n = 12 490)	Pooled analysis demonstrates no associated effect (RR, 0.95 [95% CI, 0.89-1.01]; I^2 = 56.4%)	Reasonably consistent, imprecise	Undetected	Moderate		
	Injuries	Injurious falls: 9 (n = 4306) People experiencing an injurious fall: 16 (n = 9445)	No statistically significant difference seen in nearly all studies for number of injurious falls. Pooled estimate of people experiencing injurious fall shows no associated effect (RR, 0.94 [95% CI, 0.85-1.03]; I^2 = 34.3%)	Reasonably consistent, imprecise	Undetected	Low		
	Mortality	23 (n = 9721)	No statistically significant association in pooled analysis (RR, 0.96 [95% CI, 0.79-1.17]; I^2 = 0.0%)	Inconsistent, imprecise	Undetected	Low		
Exercise 21 Studies (n = 7297) 5 Good quality, 16 fair quality	Falls	14 (n = 4663)	Associated nonsignificant reduction in falls (IRR, 0.87 [95% CI, 0.75-1.00]; I^2 = 57.3%).	Inconsistent, imprecise	Undetected	Low	Relatively small trials and less than half powered for falls or fallers. Heterogeneous interventions. Small to moderate potential for reporting bias.	Community-dwelling older adults. Average to high risk for falling (55% of RCTs recruited "high risk"; often includes history of falls or physical impairment). Difficult to identify set of effective components for implementation purposes.
	People experiencing a fall	15 (n = 4926)	Associated reduction in people experiencing a fall (RR, 0.89 [95% CI, 0.81-0.97]; I^2 = 43.9%)	Reasonably consistent, imprecise	Undetected	Low to Moderate		
	Injuries	Injurious falls: 10 (n = 4622) People experiencing an injurious fall: 5 (n = 2776)	Associated reduction in injurious falls (IRR, 0.81 [95% CI, 0.73-0.90]; I^2 = 0.0%). Point estimates showing reduction in people experiencing an injurious fall in individual trials, with IRRs ranging from 0.61 to 0.90 that were not statistically significant.	Reasonably consistent, imprecise	Undetected	Low to Moderate		
	Mortality	11 (n = 4263)	No statistically significant associated effect (RR, 0.93 [95% CI, 0.71-1.22]; I^2 = 0.0%)	Inconsistent, imprecise	Undetected	Low		

(continued)

Table. Summary of Evidence (continued)

Intervention Type, No. of Studies (No. of Participants Randomized) Study Quality	Outcome	No. of RCTs (No. of Observations)	Summary of Findings by Outcome	Consistency and Precision	Reporting Bias	EPC Assessment of Strength of Evidence	Body of Evidence Limitations	Applicability
Vitamin D 7 Studies (n = 7531) 4 Good quality, 3 fair quality	Falls	5 (n = 3529)	Mixed results: 1 trial of calcitriol showed statistically significant reduction in falls (IRR, 0.63 [95% CI, 0.47-0.84]), and 1 trial of 1-hydroxycholecalciferol showed statistically nonsignificant reduction in falls (IRR, 0.87 [95% CI, 0.59-1.30]). High-dose cholecalciferol (500 000 IU annually) showed increase in falls in vitamin D group at 36 mo (IRR, 1.16 [95% CI, 1.03-1.31]), while 2 other trials of cholecalciferol (700 IU and 800 IU daily) showed statistically nonsignificant point estimates just above 1 (IRR, 1.08 and 1.12). Pooled results show overall no association with falls (IRR, 0.97 [95% CI, 0.79-1.20]; I^2 = 75.8%).	Inconsistent, imprecise	Undetected	Low	Heterogeneity in formulations, dosing schedules, control group fall rates (reflecting heterogeneous baseline risk)	Applicable to unselected older populations of US community-dwelling adults
	People experiencing a fall	6 (n = 6519)	Mixed results: 1 trial of calcitriol showed statistically significant reduction in fallers (RR, 0.77 [95% CI, 0.61-0.98]), while another trial of 1-hydroxycholecalciferol showed statistically nonsignificant reduction (RR, 0.84 [95% CI, 0.58-1.22]). Two trials of cholecalciferol (800 IU daily and 150 000 IU every 3 mo) with RRs near 1 (1.01 and 1.08). High-dose vitamin D (500 000 IU annually) showed statistically significant increase in fallers (RR, 1.08 [95% CI, 1.03-1.14]). Pooled analysis shows no association with people experiencing a fall (RR, 0.97 [95% CI, 0.88-1.08]; I^2 = 60.3%).	Inconsistent, imprecise	Undetected	Low		
	Injuries	Injurious falls: 2 (n = 2460) People experiencing an injurious fall: 0	Mixed results: high-dose (500 000 IU annually) vitamin D showed increase in injurious falls in vitamin D group at 36 mo (IRR, 1.15 [95% CI, 1.02-1.29]), while another trial (800 IU daily) showed no difference at 24 mo (IRR, 0.84 [95% CI, 0.45-1.57]).	Inconsistent, imprecise	Undetected	Low		
	Mortality	6 (n = 7084)	No statistically significant difference in mortality (RR, 1.08 [95% CI, 0.83-1.40]; I^2 = 0.0%)	Inconsistent, imprecise	Undetected	Low		
Key Question 2. Harms Associated With Primary Care Interventions to Prevent Falls in Community-Dwelling Older Adults								
Multifactorial	Harms	4 (n = 1466)	Harms were generally minor, rare musculoskeletal issues related to exercise component of the multifactorial intervention.	Reasonably consistent, imprecise	Suspected	Low	Conclusions are limited by few studies and incomplete harms reporting	Studies of high-risk older adults
Exercise	Harms	8 (n = 4107)	No difference in serious injuries observed in 2 studies with control group comparison; several studies reported minor pain, bruising, or both associated with exercise. One of these trials reported low rate of serious injurious falls during exercise sessions (2.6/100 000 sessions).	Reasonably consistent, imprecise	Suspected	Low	75% did not report harms for control group	Community-dwelling; average to high risk for falling
Vitamin D	Harms	5 (n = 3955)	As noted above, there may be an increase in falls, people experiencing a fall, and injuries associated with the highest annual dose of vitamin D. No difference between intervention and control groups in other harms attributable to treatment.	Inconsistent, imprecise	Suspected	Low	Conclusions limited by rare events and incomplete reporting	Most studies of average-risk older adults

Abbreviations: EPC, Evidence-based Practice Center; IRR, incidence rate ratio; NA, not applicable; NR, not reported; RCT, randomized clinical trial; RR, relative risk.

Limitations

This review was limited to community-dwelling older adults and interventions that could be implemented in or referred from primary care. Trials were excluded that specifically recruited participants with neurologic diagnoses and other specific diagnoses, such as vitamin D insufficiency and osteoporosis. As such, the conclusions may not be applicable to those populations. While physical functioning outcomes (eg, changes in balance, endurance, or walking speed) and psychological outcomes (eg, falls efficacy and the fear of falling) are often associated with falls and are commonly reported in fall prevention trials, they were excluded from this review. Consistent with USPSTF methodology, the protocol prioritized objective hard health outcomes. Therefore, the intermediate outcomes were excluded in favor of falls, people experiencing a fall, and injuries due to a fall. Since this review focused on fall and fall-related morbidity and mortality, other non–fall-related outcomes that may be associated with these interventions were not examined (eg, the effect of exercise on cardiovascular outcomes, effect of vitamin D on other health outcomes).

Conclusions

Multifactorial and exercise interventions were associated with fall-related benefit, but evidence was most consistent across multiple fall-related outcomes for exercise. Vitamin D supplementation interventions had mixed results, with a high dose being associated with higher rates of fall-related outcomes.

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