Economic Evaluations of Falls Prevention Programs for Older Adults: A Systematic Review

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OBJECTIVES: To provide a comprehensive overview of economic evaluations of falls prevention programs and to evaluate the methodology and quality of these studies.

DESIGN: Systematic review of economic evaluations on falls prevention programs.

SETTING: Studies (N=31) of community-dwelling older adults (n=25), of older adults living in residential care facilities (n=3), and of both populations (n=3) published before May 2017.

PARTICIPANTS: Adults aged 60 and older.

MEASUREMENTS: Information on study characteristics and health economics was collected. Study quality was appraised using the 20-item Consensus on Health Economic Criteria.

RESULTS: Economic evaluations of falls prevention through exercise (n = 9), home assessment (n = 6), medication adjustment (n = 4), multifactorial programs (n = 11), and various other programs (n = 13) were identified. Approximately two-thirds of all reported incremental cost-effectiveness ratios (ICERs) with quality-adjusted life-years (QALYs) as outcome were below the willingness-to-pay threshold of $50,000 per QALY. All studies on home assessment and medication adjustment programs reported favorable ICERs, whereas the results of studies on exercise and multifactorial programs were inconsistent. The overall methodological quality of the studies was good, although there was variation between studies.

CONCLUSION: The majority of the reported ICERs indicated that falls prevention programs were cost-effective, but methodological differences between studies hampered direct comparison of the cost-effectiveness of program types. The results imply that investing in falls prevention programs for adults aged 60 and older is cost-effective. Home assessment programs (ICERs < $40,000/QALY) were the most cost-effective type of program for community-dwelling older adults, and medication adjustment programs (ICERs < $13,000/QALY) were the most cost-effective type of program for older adults living in a residential care facility. J Am Geriatr Soc 00:1–8, 2018.

Key words: accidental falls; prevention and control; aged; costs and cost analysis; review
of this review was to provide a comprehensive overview of economic evaluation studies of falls prevention programs for community-dwelling older adults and older adults living in residential care facilities and to evaluate the study designs, health economic characteristics, outcomes, and methodological quality of these studies. This review is focused on a broader population, and it makes a distinction between community-dwelling older adults and older adults living in residential care facilities. Furthermore, the results are compared with common willingness-to-pay (WTP) thresholds, because this is the next step in an informed decision-making process.

METHODS
The methods and reporting of this systematic review are in concordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyse statement.\(^\text{10}\) The study protocol is registered in the Prospective Register of Systematic Reviews (number CRD42017071726).

Literature search
Relevant studies were identified through systematic literature searches in several databases (Supplementary Appendix S1). The search strategies were developed in consultation with an information specialist. Reference lists and citation indices of the included articles were inspected to identify additional relevant studies. Searches were restricted to English-language articles published in peer-reviewed journals before May 2017.

Study selection
This study included trial-based economic evaluations (TBEEs) and model-based economic evaluations (MBEEs).\(^\text{11}\) In TBEEs, a cost-effectiveness study is conducted alongside an effectiveness trial. Available evidence is used to estimate the cost-effectiveness of programs in MBEEs. Only studies in which costs and effects of 2 or more programs were compared using an incremental cost-effectiveness analysis (CEA) were included.\(^\text{11}\) CEA, cost-utility analyses (CUAs), and cost-benefit analyses (CBAs) were considered for inclusion. In a CEA, costs and clinical effects (e.g., falls prevented) are used as outcomes, whereas costs and generic utility measures are used as outcomes in a CUA. Quality-adjusted life-years (QALYs) are generally used as a generic utility measure in a CUA. In a CBA, costs and effects of programs are expressed in monetary terms, yielding net monetary benefits. For this review, only studies of adults aged 60 and older were included. The results of studies of community-dwelling older adults and older adults living in residential care facilities are reported separately in this review. Studies that were primarily focused on fracture prevention were excluded.

Data extraction
After duplicate studies were deleted, one reviewer (BO) screened the titles and abstracts of the remaining studies. A second reviewer (RO) screened a subset of the titles to check for consistency. Two reviewers (BO, RO) independently read the full text of included studies. After noneligible studies were excluded, relevant study characteristics and health and economic data were retrieved for analysis. When the health economic perspective or baseline fall risk was not reported in an article, perspective or baseline fall risk was derived from the methods or results section of the article (BO, RO). A second reviewer independently checked the data extraction (BO/RO). A third reviewer (SP) helped resolve discrepancies.

Outcome
The primary outcome measure was the incremental cost-effectiveness ratio (ICER). An ICER is a standard outcome in economic evaluations and is expressed as additional costs per unit of outcome gained for the intervention over usual care. The outcome as defined in the individual studies is reported. If an ICER was not reported, but a full economic evaluation was performed, the health economic results were reported descriptively. To compare price levels between countries, all ICERS were converted to 2016 U.S. dollars using purchasing power parity rates and the Consumer Price Index.\(^\text{12,13}\) To maintain comparability of the results of the included CUA with QALY as the outcome, a WTP threshold of $50,000 per QALY gained was applied, which is a widely accepted threshold in the United States.\(^\text{14}\) Because the threshold of $50,000 has been in use since the 1980s, we used this as a lower boundary, and the outcomes were compared with a commonly used inflation-adjusted threshold of $100,000 per QALY.\(^\text{15}\) The WTP threshold is the maximum amount society is willing to pay for gaining 1 additional QALY. When the ICER is lower than the threshold, the program is considered more cost-effective than the control condition. The ICERs of CEA were not compared with a threshold, because there are no generally accepted thresholds for outcomes other than QALYs.

Quality assessment
In concordance with the Cochrane collaboration guidelines,\(^\text{16}\) the quality of the studies was assessed using the extended Consensus on Health Economic Criteria (CHEC),\(^\text{17}\) which contains 20 items covering internal and external validity of economic evaluation studies (Supplementary Appendix S2). Each item on the CHEC checklist was scored as “no” (0), “suboptimal” (0.5), “yes” (1), or “not applicable.”\(^\text{18}\) The sum score (%) for each study was reported in this review. Two reviewers (BO, RO) independently assessed the quality of the studies and scored them. A third reviewer (SP) helped resolve discrepancies. The correlation between the total quality scores and ICERs are expressed in a Pearson correlation coefficient. Separate correlation coefficients were calculated for CUA, CEA, falls prevention program type, and population. The critical p-value was set at .05.

RESULTS

Literature search and study selection
The literature search yielded 5,209 studies. After duplicates were removed, the titles and abstracts of 3,063 studies were screened for relevance, resulting in exclusion of 2,980 studies because they were not primarily focused on falls
prevention programs or contained no economic evaluation. The full text of 83 studies was read for eligibility assessment. Fifty-four studies were excluded for the following reasons: no full economic evaluation ($n = 32$), no original research ($n = 11$), population younger than 60 ($n = 6$), and protocol article ($n = 5$). Two additional studies were identified through scanning the reference lists of included studies. Thirty-one studies were included in the systematic review (Figure 1).

The studies included were published between 1996 and 2017. The study populations were community-dwelling older adults ($n = 25$), older adults living in residential care facilities ($n = 3$), or both ($n = 3$). The following falls prevention programs were identified: exercise ($n = 9$), home assessment ($n = 6$), medication adjustment ($n = 4$), multifactorial programs ($n = 11$), and other programs ($n = 13$).

The content of multifactorial programs can be found in Supplementary Appendix S3. Most of the studies compared falls prevention programs with usual care or no program. The number of falls prevented and QALYs were mainly used as outcomes. Study characteristics are reported in Supplementary Table S1.

Quality assessment

Quality scores ranged from 62% to 97% (Table 1, Supplementary Table S2). The average score of 84% shows that the overall methodological quality was good. The quality of the studies on home assessment and medication adjustment programs had the lowest scores on average (82%), and exercise and other programs had the highest scores (88%). The studies reporting a cost saving or cost-effective falls prevention program had an average score of 83%. Studies that did not report a cost saving or cost-effective program scored 91% on average. There was no significant correlation between quality score and reported ICERs for CUAs ($r(44)=-0.04$, $p=.81$) and CEAs ($r(44)=-0.14$, $p=.37$). The association remained nonsignificant when the correlation analysis was performed for program type and population.

Economic evaluations

Nineteen studies performed a CUA with QALYs as the outcome. In the majority of these studies, QALYs were calculated by multiplying utility values by remaining years of life corresponding to the time horizon of the studies. Thirteen studies used utility values that were derived from the EQ-5D. One study used the Medical Outcomes Study 36-item Short-Form Survey (SF-36), and one study used the EQ-5D and SF-36. Three studies did not report how utility values were derived. A societal perspective ($n = 13$) was applied as often as a healthcare perspective ($n = 13$) (Supplementary Table S3). All studies with a healthcare perspective included program costs and other healthcare costs in their analyses.
Table 1. Consensus on Health Economic Criteria Quality Assessment Items and Scores, Subdivided by Falls Prevention Program

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Quality score, %</th>
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<tbody>
<tr>
<td><strong>Exercise programs</strong></td>
<td></td>
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<tr>
<td>Church et al. 2011</td>
<td>83</td>
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<tr>
<td>Church et al. 2012</td>
<td>83</td>
</tr>
<tr>
<td>Davis et al. 2011</td>
<td>89</td>
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<tr>
<td>Farag et al. 2015</td>
<td>92</td>
</tr>
<tr>
<td>McLean et al. 2016</td>
<td>95</td>
</tr>
<tr>
<td>Munro et al. 2004</td>
<td>72</td>
</tr>
<tr>
<td>Robertson et al. 2001 (1)</td>
<td>94</td>
</tr>
<tr>
<td>Robertson et al. 2001 (2)</td>
<td>91</td>
</tr>
<tr>
<td>Robertson et al. 2011 (3)</td>
<td>91</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>88</td>
</tr>
<tr>
<td><strong>Home assessment programs</strong></td>
<td></td>
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<tr>
<td>Campbell et al. 2005</td>
<td>78</td>
</tr>
<tr>
<td>Church et al. 2012</td>
<td>83</td>
</tr>
<tr>
<td>Pega et al. 2016</td>
<td>83</td>
</tr>
<tr>
<td>Sahlen et al. 2008</td>
<td>84</td>
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<tr>
<td>Saikled et al. 2000</td>
<td>85</td>
</tr>
<tr>
<td>Smith et al. 1998</td>
<td>76</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>82</td>
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<tr>
<td><strong>Medication adjustment programs</strong></td>
<td></td>
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<tr>
<td>Church et al. 2011</td>
<td>83</td>
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<tr>
<td>Church et al. 2012</td>
<td>83</td>
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<tr>
<td>Church et al. 2015</td>
<td>93</td>
</tr>
<tr>
<td>Frick et al. 2010</td>
<td>68</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>82</td>
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<tr>
<td><strong>Multifactorial programs</strong></td>
<td></td>
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<tr>
<td>Church et al. 2011</td>
<td>83</td>
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<tr>
<td>Church et al. 2012</td>
<td>83</td>
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<tr>
<td>Church et al. 2015</td>
<td>93</td>
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<td>Farag et al. 2014</td>
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<td>Heinrich et al. 2013</td>
<td>86</td>
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<tr>
<td>Hendriks et al. 2008</td>
<td>89</td>
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<td>Jenkyn et al. 2012</td>
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<td>Rizzo et al. 1996</td>
<td>62</td>
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<tr>
<td><strong>Average</strong></td>
<td>83</td>
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<tr>
<td><strong>Other programs</strong></td>
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<tr>
<td>Church et al. 2011</td>
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<td>Church et al. 2012</td>
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<tr>
<td>Church et al. 2015</td>
<td>93</td>
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<tr>
<td>Lee et al. 2013</td>
<td>90</td>
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<tr>
<td>Patil et al. 2016</td>
<td>97</td>
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<td>Poole et al. 2015</td>
<td>75</td>
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<td>Sach et al. 2007</td>
<td>89</td>
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<tr>
<td>Cockayne et al. 2017</td>
<td>63</td>
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<tr>
<td>Mori et al. 2017</td>
<td>93</td>
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<tr>
<td>Van Haastregt et al. 2013</td>
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</tr>
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Scores expressed as percentage of maximum score.

(Supplementary Table S4 and S5). Nineteen TBEEs and 12 MBEES were identified. The most commonly applied time horizon in TBEEs was 1 year (58%), followed by 2 years (11%). Of the MBEES, the most commonly applied time horizon was a lifetime horizon (50%). Ten TBEES (53%) applied bootstrapping to address sampling uncertainty. The main cost-effectiveness findings of this review were subdivided according to program type (Supplementary Table S3).

Figure 2 provides a graphical overview of all reported ICERS in the CUAs, subdivided according to program type. In this figure, a distinction was made between community-dwelling older adults and older adults living in residential care facilities. Approximately two-thirds of the ICERS with QALYs as the outcome were below the WTP threshold of $50,000 per QALY (Figure 2), and 86% were below the threshold of $100,000 per QALY. All ICERS of home assessment and medication adjustment programs were cost-effective given both thresholds. Half of the reported ICERS of exercise programs and multifactorial programs and more than two-thirds of the reported ICERS of various other programs indicated that these programs were cost-effective when a threshold of $50,000 per QALY was applied, although all ICERS of exercise programs and the vast majority of the ICERS of multifactorial programs were below the threshold of $100,000 per QALY.

Figure 3 presents all reported ICERS with falls as the outcome. The majority of the ICERS of exercise programs and all ICERS of medication adjustment programs were less than $2,000 per fall prevented (Figure 3). In contrast, most of the ICERS of multifactorial programs were higher than $2,000 per fall prevented.

**Exercise programs**

Nine economic evaluations of exercise programs were identified. The ICERS of CUAs ranged from $30,013 to $80,860 per QALY. Six ICERS of CUAs were cost-effective based on thresholds of $50,000 per QALY and $100,000 per QALY. One study reported that once-weekly and twice-weekly resistance training were more cost-effective than twice-weekly balance and tone classes.

The ICERS of CEAs on exercise programs ranged from $186 to $4,446 per (injurious) fall prevented. One study reported relatively low ICERS of CEAs for older populations (≥75). Two other studies showed that tai chi and group-based exercise in a high-risk population were the most cost-effective programs.

**Home assessment programs**

Economic evaluations of home assessment programs were performed in 6 studies. The ICERS of CUAs ranged from $2,158 to $39,281 per QALY and were all below thresholds of $50,000 and $100,000 per QALY.

The ICERS of CEAs ranged from $548 to $5,313 per fall prevented. The studies with older populations (≥75) reported lower ICERS than the studies with younger populations (≤65).

**Medication adjustment programs**

Four economic evaluations of medication adjustment programs were identified. Two reported the ICERS of CUAs on medication review or withdrawal and showed that it was cost saving in a population of older adults living in a residential care facility. One showed that the program was cost-effective in community-dwelling older adults. The fourth compared the ICERS of CUAs of a medication adjustment program with those of exercise, home assessment, multifactorial, and vitamin D programs and reported that medication adjustment was the least expensive and most effective program in community-dwelling older adults.
The first three studies also showed relatively low or cost-saving ICERs of CEAs on a medication review and withdrawal program.\textsuperscript{19,20,33} Multifactorial programs

Eleven studies performed an economic evaluation of multifactorial programs.\textsuperscript{19,20,33,35–42} The ICERs of CUAs ranged from $20,427 to $112,598 per QALY. Seven of 14 ICERs were below the threshold of $50,000 per QALY, and 10 were below $100,000 per QALY. Two studies reported that their program in community-dwelling older adults (≥65) was less effective and more costly than the control condition.\textsuperscript{37,41}

The ICERs of CEAs ranged from $1,666 to $125,909 per fall prevented. The ICERs were lower in a population living in a residential care facility than in a community-dwelling population. In both populations, a program consisting of modification of risk factors, information sessions, and follow-up had the lowest ICERs.

Other programs

Economic evaluations of a variety of other falls prevention programs (vitamin D, cataract surgery, cardiac pacing, podiatry care, bisphosphonates and exercise, cognitive behavioral therapy) were reported in 13 studies.\textsuperscript{19,20,33,43–49} Eleven ICERs of CUAs were reported in these studies, of which 7 programs were cost saving or cost-effective.\textsuperscript{19,20,33,43,47} Nine were cost-effective given a threshold of $100,000 per QALY. One study showed that, as age increases, the costs per QALY decrease.\textsuperscript{45}

Additional information on the other programs can be found in Supplementary Table S3.

DISCUSSION

This systematic review provides a comprehensive overview of the results of 31 economic evaluations of falls prevention programs for community-dwelling older adults and older adults living in residential care facilities. In general, medication adjustment programs and home assessment programs had the most favorable results because the lowest ICERs were reported for these program types, although when a higher WTP threshold of $100,000 was applied, the majority of the remaining program types (exercise, multifactorial, other) were also cost-effective. Given an earlier published review,\textsuperscript{2} it appears that medication adjustment programs

Figure 2. Overview of incremental cost-effectiveness ratios (ICERs) per falls prevention program, with costs per quality-adjusted life year (QALY) gained as outcome. Only ICERs expressed as costs per QALY gained are included. Negative ICERs indicating less effect at higher costs and cost-saving ICERs are not included in this figure.

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and vitamin D supplementation and cataract surgery are falls prevention programs that may also be cost saving. Methodological differences between studies hampered direct comparison of the cost-effectiveness of program types. The majority of the TBEEs were powered for falls and not for costs, which may have contributed to the heterogeneity of the results, because costs often have a very skewed distribution.9

These findings are mainly based on CUAs because there is no generally accepted cost-effectiveness threshold for costs per fall prevented.

This review shows that home assessment programs are the most cost-effective type of program for community-dwelling older adults and that medication adjustment programs are the most cost-effective for older adults living in residential care facilities. The results for mixed populations were less consistent, but for higher WTP thresholds, exercise, home assessments, and medication adjustment programs were all cost-effective. In general, multifactorial programs and other programs were less favorable, but these programs were more frequently assessed than home assessment and medication adjustment programs. Multifactorial programs were assessed 11 times, and other programs were assessed 13 times, whereas, when home assessment and medication adjustment programs were combined, 10 assessments were made. This could have contributed to a wider range of results. A possible explanation for the less-favorable cost-effectiveness results for exercise and multifactorial programs is that the program costs for these programs are likely to be higher than the program costs for home assessment and medication review programs. Home assessment and medication review programs are often one-time-only programs, whereas exercise and multifactorial programs consist of multiple classes or appointments. A difference in health economic perspective or baseline fall risk between studies could have contributed to differences in cost-effectiveness results as well.

The cost-effectiveness of interventions depends on the WTP threshold. For this study, WTP thresholds of $50,000 and $100,000 for 1 QALY gained were applied, but WTP values in general have no solid scientific basis.50 Choosing a relevant WTP threshold is essential for policy-making, because the inappropriate use of WTP thresholds might lead to inappropriate decisions. For example, the cost-effectiveness of falls prevention programs severely decreases when a lower threshold of $20,000 per QALY is applied. In this case, the majority of the ICERs reported are above the threshold. Conversely, the cost-effectiveness increased substantially when a higher threshold of $100,000 was applied.

Studies performed on older adults living in residential care facilities reported slightly more favorable ICERs than those performed on community-dwelling older adults, although it cannot be concluded that falls prevention programs are more cost-effective in adults living in residential care facilities, because only 3 studies were performed in these populations. Additional research is needed to properly compare the results for different populations in economic evaluations of falls prevention programs.

Studies on older populations reported more favorable ICERs than studies on younger populations, although 90% of the ICERs of CUAs originated from studies of adults aged 65 to 75, and 10% originated from studies of adults aged 75 and older. Therefore, it is not possible to draw firm conclusions about age differences. A possible explanation for the observed differences between age groups is that older people are more likely to fall,51 so prevention programs can thus prevent more falls. Older people are also more often hospitalized after a fall-related injury, which is associated with high healthcare costs.51 Consequently, more costs could be saved in older people.

Relevant study quality differences between falls prevention program types could not be identified. On average, studies reporting a cost-saving or cost-effective falls prevention program had lower quality scores than studies not describing a cost-effective falls prevention program (83% vs 91%), but the difference was small and therefore not likely to be influential.

One of the strengths of this review is that standardized methods for conducting and reporting systematic reviews were followed. All reported ICERs were converted to 2016 U.S. dollars, which allows for comparison of cost data. Differences resulting from purchasing power and inflation were eliminated. Another strength of this study is the extensive health economic quality assessment.

This review also has several limitations. Although WTP thresholds differ between countries, the same 2 WTP thresholds were applied for all CUAs. There might have been selection bias because the search was limited to English-language articles that were published in peer-reviewed scientific journals. In determining the overall cost-effectiveness of home assessment and medication adjustment programs, the effectiveness of these programs has to be considered as well. Reviews have shown that evidence of the effectiveness of these programs is fairly inconsistent.46 There is likely to be publication bias in economic evaluations because economic evaluations are less likely to be performed when an intervention is ineffective.52 Therefore, the findings presented in this review are likely to overestimate the cost-effectiveness of falls prevention programs in general.

Future economic evaluations of falls prevention programs should be designed, conducted, and reported in accordance with current guidelines for economic evaluations to increase comparability, which is essential for informing decision-making.53,54 In addition, comprehensive cost-effectiveness models comparing multiple falls prevention programs such as described previously provide insight into the relative cost-effectiveness of different program types in the same population.19,20,33 Furthermore, QALYS are preferred as the outcome in addition to clinical effect measures because QALYS can be compared with established WTP thresholds. Comparing the QALYS in this review with 2 WTP thresholds shows that the majority of falls prevention programs are cost-effective. Moreover, some studies show that falls prevention is effective and cost saving. Thus, decision-makers should consider implementing falls prevention programs, also considering the increasing effect of fall-related injuries in older adults. Future studies should clearly report whether they target high-risk, low-risk, or mixed populations because the baseline fall risk is an important determinant of cost-effectiveness.2 This is important for identifying whether falls prevention programs are more cost-effective for certain risk groups because some studies reported more favorable results for older adults with higher fall risk.

This review indicates that investing in falls prevention programs for adults aged 60 and older is cost-effective,
particularly home assessment for community-dwelling older adults and medication adjustment programs for older adults living in residential care facilities. Programs were found to be more cost-effective as the age of participants increases.

ACKNOWLEDGMENTS

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REFERENCES


SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

Supplementary Table S1. Main study characteristics, subdivided by living situation.

Supplementary Table S2. CHEC quality assessment items and scores.

Supplementary Table S3. Main economic evaluation findings, subdivided by falls prevention program.

Supplementary Table S4. Costs and uncertainty handling trial-based economic evaluations.

Supplementary Table S5. Costs and uncertainty handling model-based economic evaluations.

Supplementary Text S1. Search strategy for cost-effectiveness studies on falls prevention programs in older adults.

Supplementary Text S2. CHEC extended scoring instruction.

Supplementary Text S3. Content of multifactorial falls prevention programs.