RESEARCH ARTICLE

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

Branko F. Olij, MSc,[1] Robbin H. Ophuis, MSc,*[1] Suzanne Polinder, PhD,* Ed F. van Beeck, MD, PhD,* Alex Burdorf, PhD,* Martien J.M. Panneman, MSc,[†] and Carolyn Shanty Sterke, PhD*[‡]*

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

Fall-related injuries have a large effect on global health in older adults.[1] Furthermore, consequences of fall-related injuries are associated with higher costs for medical consultation and treatment.[2] Mean healthcare costs for an injurious fall treated at the emergency department are $11,450, and this amount increases with age.[3] Almost two-thirds of all fall-related healthcare costs can be attributed to hospital and nursing home admissions.[3] Studies have shown that exercise programs and programs combining multiple components, such as exercise and home assessment, reduce fall-related injuries in older adults.[4–7] Although effective falls prevention programs are available, the occurrence of falls in older adults is still high. Because financial resources in health care are limited, it is important that policy-makers invest in implementation of cost-effective falls prevention programs. An up-to-date overview of all published economic evaluations of falls prevention programs and their methodological quality is relevant because the results can inform policy decisions. Previous systematic reviews of economic evaluations of fall prevention programs have shown that programs consisting of home visits[8] and of strength and balance exercises[9] are cost-effective. A comprehensive overview of economic evaluations of falls prevention programs was limited to community-dwelling older adults.[9] Since that publication, 22 new economic evaluations of falls prevention programs have been published. Therefore, an update is deemed relevant. The aim

From the *Department of Public Health, Erasmus MC—University Medical Center Rotterdam, the Netherlands; [†]VeiligheidNL, Amsterdam, the Netherlands; and the [‡]Aafje, Rotterdam, the Netherlands.

Address correspondence to Branko F. Olij, Erasmus MC—University Medical Center Rotterdam, Department of Public Health, PO Box 2040, 3000 CA, Rotterdam, The Netherlands. E-mail: b.olij@erasmusmc.nl

[1]These authors were equal contributors.

DOI: 10.1111/jgs.15578

0002-8614/18/$15.00

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.[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).[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.[11] CEAs, 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.[12,13] To maintain comparability of the results of the included CUAs 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.[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.[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 CEAs 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,[16] the quality of the studies was assessed using the extended Consensus on Health Economic Criteria (CHEC),[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."[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 CUAs, CEAs, 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

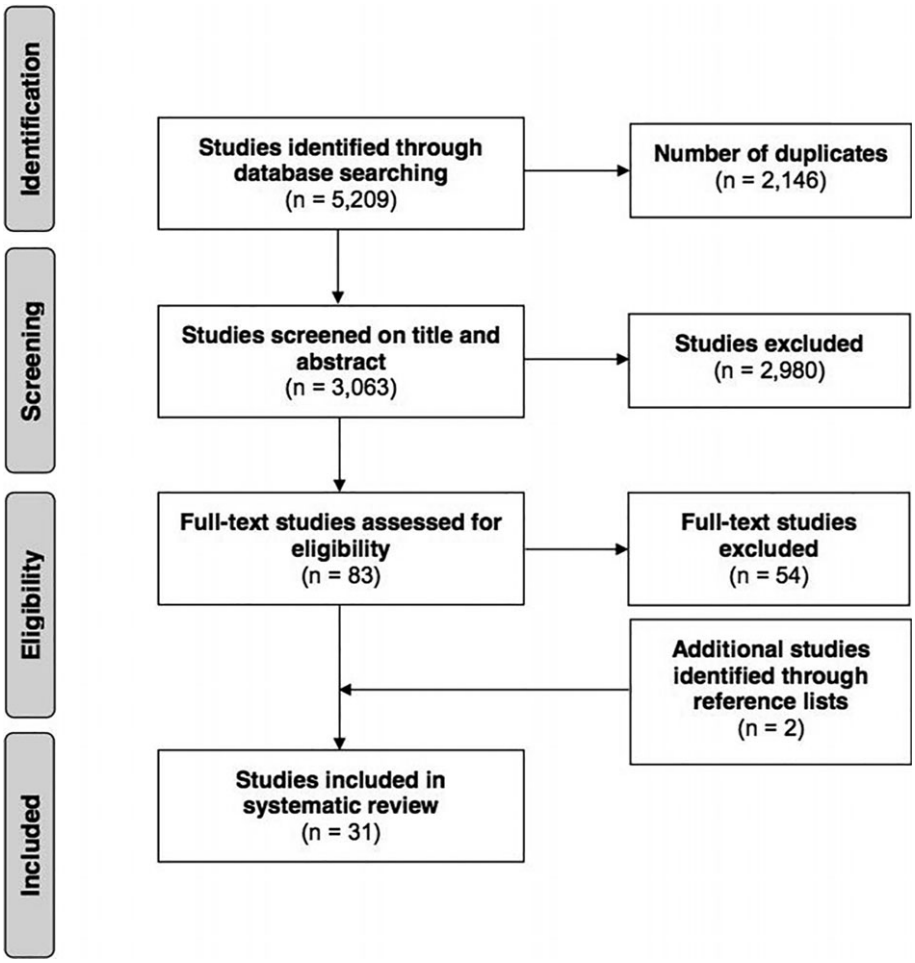

Figure 1. Flowchart of search for studies of cost-effectiveness of falls prevention programs in older adults.

Table 1. Consensus on Health Economic Criteria Quality Assessment Items and Scores, Subdivided by Falls Prevention Program

Author, Year	Quality score, %
Exercise programs	
Church et al. 2011[19]	83
Church et al. 2012[20]	83
Davis et al. 2011[21]	89
Farag et al. 2015[22]	92
McLean et al. 2015[23]	95
Munro et al. 2004[24]	72
Robertson et al. 2001 (1)[26]	94
Robertson et al. 2001 (2)[25]	91
Robertson et al. 2011 (3)[27]	91
Average	88
Home assessment programs	
Campbell et al. 2005[28]	78
Church et al. 2012[20]	83
Pega et al. 2016[29]	83
Sahlen et al. 2008[30]	84
Salkeld et al. 2000[31]	85
Smith et al. 1998[32]	76
Average	82
Medication adjustment programs	
Church et al. 2011[19]	83
Church et al. 2012[20]	83
Church et al. 2015[33]	93
Frick et al. 2010[34]	68
Average	82
Multifactorial programs	
Church et al. 2011[19]	83
Church et al. 2012[20]	83
Church et al. 2015[33]	93
Farag et al. 2014[35]	75
Heinrich et al. 2013[36]	86
Hendriks et al. 2008[37]	89
Irvine et al. 2010[38]	92
Jenkyn et al. 2012[39]	79
Müller et al. 2014[40]	83
Peeters et al. 2011[41]	92
Rizzo et al. 1996[42]	62
Average	83
Other programs	
Church et al. 2011[19]	83
Church et al. 2012[20]	83
Church et al. 2015[33]	93
Lee et al. 2013[44]	90
Patil et al. 2016[46]	97
Poole et al. 2015[47]	75
Sach et al. 2007[48]	89
Cockanye et al. 2017[43]	63
Mori et al. 2017[45]	93
Van Haastregt et al. 2013[49]	94
Average	86

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.[19–27] 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.[21]

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).[25–27] Two other studies showed that tai chi and group-based exercise in a high-risk population were the most cost-effective programs.[19,20]

Home assessment programs

Economic evaluations of home assessment programs were performed in 6 studies.[20,28–32] 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.[19,20,33,34] 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.[19,33] One showed that the program was cost-effective in community-dwelling older adults.[20] 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.[34]

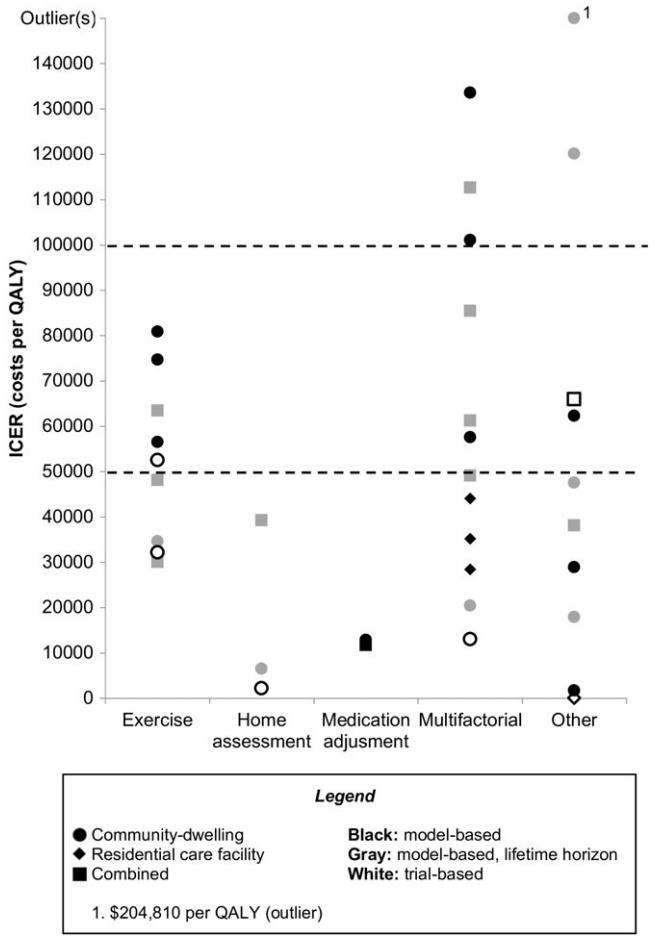

Figure 2. Overview of incremental cost-effectiveness ratios (ICERs) per falls prevention program, with costs per quality-adjusted life year (QALY) gained as outcome. Only ICERs expressed as costs per QALY gained are included. Negative ICERs indicating less effect at higher costs and cost-saving ICERs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

The first three studies also showed relatively low or cost saving ICERs of CEAs on a medication review and withdrawal program.[19,20,33]

Multifactorial programs

Eleven studies performed an economic evaluation of multifactorial programs.[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.[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.[19,20,33,43–49] Eleven ICERs of CUAs were reported in these studies, of which 7 programs were cost saving or cost-effective.[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.[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,[2] it appears that medication adjustment programs

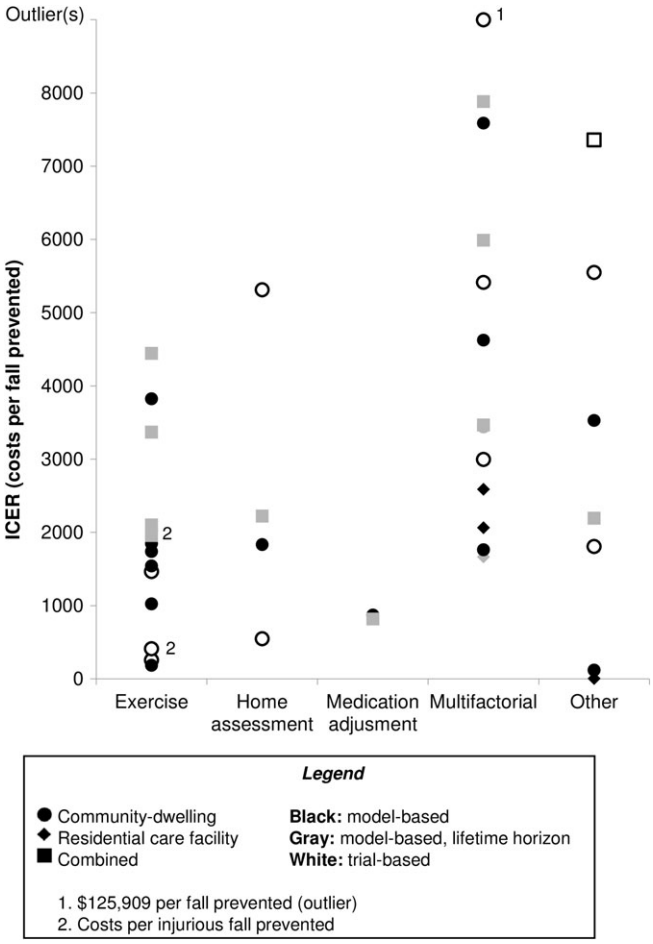

Figure 3. Overview of incremental cost-effectiveness ratios (ICERs) per falls prevention program, with costs per fall prevented as outcome. Only ICERs expressed as costs per fall prevented are included. Negative ICERs indicating less effects at higher costs and cost-saving ICERs are not included in this figure.

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 program 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.[4,6] 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

The authors thank W. Bramer, information specialist, Erasmus MC—University Medical Center Rotterdam, for his contributions to the development of the literature search strategy.

Conflict of Interest: None.

Author Contributions: Study concept and design: Olij, Ophuis, Polinder, van Beeck, Sterke. Literature search and data analysis: Olij, Ophuis, Polinder, Sterke. Manuscript preparation: Olij, Ophuis, Polinder, Sterke. Critical revision of manuscript: Olij, Ophuis, Polinder, van Beeck, Burdorf, Panneman, Sterke.

Sponsor's Role: There was no involvement of sponsors in any part of this project.

REFERENCES

1. Haagsma JA, Graetz N, Bolliger I et al. The global burden of injury: Incidence, mortality, disability-adjusted life years and time trends from the Global Burden of Disease study 2013. Inj Prev 2016;22:3–18.
2. Davis JC, Robertson MC, Ashe MC, Liu-Ambrose T, Khan KM, Marra CA. International comparison of cost of falls in older adults living in the community: A systematic review. Osteoporos Int 2010;21:1295–1306.
3. Hartholt KA, Polinder S, Van der Cammen TJ et al. Costs of falls in an ageing population: A nationwide study from the Netherlands (2007–2009). Injury 2012;43:1199–1203.
4. Karlsson MK, Magnusson H, von Schewelov T, Rosengren BE. Prevention of falls in the elderly—a review. Osteoporos Int 2013;24:747–762.
5. Sherrington C, Michaleff ZA, Fairhall N et al. Exercise to prevent falls in older adults: An updated systematic review and meta-analysis. Br J Sports Med 2017;51:1750–1758.
6. Stubbs B, Brefka S, Denkinger M. What works to prevent falls in community-dwelling older adults?. An umbrella review of meta-analyses of randomized controlled trials. J Am Phys Ther Assoc 2015;95:1095–1110.
7. Tricco AC, Thomas SM, Veroniki AA et al. Comparisons of interventions for preventing falls in older adults: A systematic review and meta-analysis. JAMA 2017;318:1687–1699.
8. Corrieri S, Heider D, Riedel-Heller SG, Matschinger H, Konig HH. Cost-effectiveness of fall prevention programs based on home visits for seniors aged over 65 years: A systematic review. Int Psychogeriatr 2011;23:711–723.
9. Davis JC, Robertson MC, Ashe MC, Liu-Ambrose T, Khan KM, Marra CA. Does a home-based strength and balance programme in people aged > or = 80 years provide the best value for money to prevent falls? A systematic review of economic evaluations of falls prevention interventions. Br J Sports Med 2010;44:80–89.
10. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Int J Surg 2010;8:336–341.
11. Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. Methods for the Economic Evaluation of Health Care Programmes, 4th Ed. Oxford: Oxford University Press, 2015.
12. Purchasing Power Parities 2017. Organisation for Economic Co-operation and Development (online). Available at https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm#indicator-chart Accessed August 23, 2017.
13. Monthly Comparative Price Levels 2017. Organisation for Economic Co-operation and Development (online). Available at http://stats.oecd.org/Index.aspx?DataSetCode=CPL Accessed August 23, 2017.
14. Weintraub WS, Cohen DJ. The limits of cost-effectiveness analysis. Circ Cardiovasc Qual Outcomes 2009;2:55–58.
15. Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of the $50,000-per-QALY threshold. N Engl J Med 2014;371:796–797.
16. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions, 4th Ed. John Wiley & Sons; 2011.
17. Evers S, Goossens M, de Vet H, van Tulder M, Ament A. Criteria list for assessment of methodological quality of economic evaluations: Consensus on health economic criteria. Int J Technol Assess Health Care 2005;21:240–245.
18. Ophuis RH, Lokkerbol J, Heemskerk SC, van Balkom AJ, Hiligsmann M, Evers SM. Cost-effectiveness of interventions for treating anxiety disorders: A systematic review. J Affect Disord 2017;210:1–13.
19. Church J, Goodall S, Norman R, Haas M. An economic evaluation of community and residential aged care falls prevention strategies in NSW. N S W Public Health Bull 2011;22:60–68.
20. Church J, Goodall S, Norman R, Haas M. The cost-effectiveness of falls prevention interventions for older community-dwelling Australians. Aust N Z J Public Health 2012;36:241–248.
21. Davis JC, Marra CA, Robertson MC et al. Economic evaluation of dose-response resistance training in older women: A cost-effectiveness and cost-utility analysis. Osteoporos Int 2011;22:1355–1366.
22. Farag I, Howard K, Hayes AJ et al. Cost-effectiveness of a home-exercise program among older people after hospitalization. J Am Med Dir Assoc 2015;16:490–496.
23. McLean K, Day L, Dalton A. Economic evaluation of a group-based exercise program for falls prevention among the older community-dwelling population. BMC Geriatr 2015;15:33.
24. Munro JF, Nicholl JP, Brazier JE, Davey R, Cochrane T. Cost effectiveness of a community based exercise programme in over 65 year olds: cluster randomised trial. J Epidemiol Community Health 2004;58:1004–1010.
25. Robertson M, Devlin N, Gardner M, Campbell A. Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 1: Randomised controlled trial. BMJ 2001;322:1–6.
26. Robertson M, Devlin N, Scuffham P, Gardner M, Buchner D, Campbell A. Economic evaluation of a community based exercise programme to prevent falls. J Epidemiol Community Health 2001;55:600–606.
27. Robertson M, Gardner M, Devlin N, McGee R, Campbell A. Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 2: Controlled trial in multiple centres. BMJ 2011;322:1–5.
28. Campbell AJ, Robertson MC, La Grow SJ et al. Randomised controlled trial of prevention of falls in people aged > or = 75 with severe visual impairment: The VIP trial. BMJ 2005;331:817.
29. Pega F, Kvizhinadze G, Blakely T, Atkinson J, Wilson N. Home safety assessment and modification to reduce injurious falls in community-dwelling older adults: cost-utility and equity analysis. Inj Prev 2016;22:420–426.
30. Sahlen KG, Lofgren C, Mari Hellner B, Lindholm L. Preventive home visits to older people are cost-effective. Scand J Public Health 2008;36:265–271.
31. Salkeld G, Cumming R, O'Neill E, Thomas M, Szonyi G, Westbury C. The cost effectiveness of a home hazard reduction program to reduce falls among older persons. Aust N Z J Public Health 2000;24:265–271.
32. Smith R, Widiatmoko D. The cost-effectiveness of home assessment and modification to reduce falls in the elderly. Aust N Z J Public Health 1998;22:436–440.
33. Church JL, Haas MR, Goodall S. Cost effectiveness of falls and injury prevention strategies for older adults living in residential aged care facilities. Pharmacoeconomics 2015;33:1301–1310.
34. Frick KD, Kung JY, Parrish JM, Narrett MJ. Evaluating the cost-effectiveness of fall prevention programs that reduce fall-related hip fractures in older adults. J Am Geriatr Soc 2010;58:136–141.
35. Farag I, Howard K, Ferreira ML, Sherrington C. Economic modelling of a public health programme for fall prevention. Age Ageing 2014;44:409–414.
36. Heinrich S, Rapp K, Stuhldreher N, Rissmann U, Becker C, Konig HH. Cost-effectiveness of a multifactorial fall prevention program in nursing homes. Osteoporos Int 2013;24:1215–1223.
37. Hendriks MR, Evers SM, Bleijlevens MH, van Haastregt JC, Crebolder HF, van Eijk JT. Cost-effectiveness of a multidisciplinary fall prevention program in community-dwelling elderly people: A randomized controlled trial (ISRCTN 64716113). Int J Technol Assess Health Care 2008;24:193–202.
38. Irvine L, Conroy SP, Sach T et al. Cost-effectiveness of a day hospital falls prevention programme for screened community-dwelling older people at high risk of falls. Age Ageing 2010;39:710–716.
39. Jenkyn KB, Hoch JS, Speechley M. How much are we willing to pay to prevent a fall?. Cost-effectiveness of a multifactorial falls prevention program for community-dwelling older adults. Can J Aging 2012;31:121–137.
40. Müller D, Borsi L, Stracke C, Stock S, Stollenwerk B. Cost-effectiveness of a multifactorial fracture prevention program for elderly people admitted to nursing homes. Eur J Health Econ 2014;16:517–527.
41. Peeters GM, Heymans MW, de Vries OJ, Bouter LM, Lips P, van Tulder MW. Multifactorial evaluation and treatment of persons with a high

risk of recurrent falling was not cost-effective. Osteoporos Int 2011;22: 2187–2196.

42. Rizzo J, Baker D, McAvay G, Tinetti M. The cost-effectiveness of a multifactorial targeted prevention program for falls among community elderly persons. Med Care 1996;34:954–969.
43. Cockayne S, Adamson J, Clarke A et al. Cohort randomised controlled trial of a multifaceted podiatry intervention for the prevention of falls in older people (The REFORM Trial). PLoS One 2017;12:e0168712.
44. Lee RH, Weber T, Colon-Emeric C. Comparison of cost-effectiveness of vitamin D screening with that of universal supplementation in preventing falls in community-dwelling older adults. J Am Geriatr Soc 2013;61:707–714.
45. Mori T, Crandall CJ, Ganz DA. Cost-effectiveness of combined oral bisphosphonate therapy and falls prevention exercise for fracture prevention in the USA. Osteoporos Int 2017;28:585–595.
46. Patil R, Kolu P, Raitanen J et al. Cost-effectiveness of vitamin D supplementation and exercise in preventing injurious falls among older home-dwelling women: Findings from an RCT. Osteoporos Int 2016;27:193–201.
47. Poole CD, Smith J, Davies JS. Cost-effectiveness and budget impact of empirical vitamin D therapy on unintentional falls in older adults in the UK. BMJ Open 2015;5:e007910.
48. Sach TH, Foss AJ, Gregson RM et al. Falls and health status in elderly women following first eye cataract surgery: An economic evaluation conducted alongside a randomised controlled trial. Br J Ophthalmol 2007;91:1675–1679.
49. van Haastregt JC, Zijlstra GA, Hendriks MR, Goossens ME, van Eijk JT, Kempen GI. Cost-effectiveness of an intervention to reduce fear of falling. Int J Technol Assess Health Care 2013;29:219–226.
50. Shiroiwa T, Sung YK, Fukuda T, Lang HC, Bae SC, Tsutani K. International survey on willingness-to-pay (WTP) for one additional QALY gained: What is the threshold of cost effectiveness? Health Econ 2010;19:422–437.
51. Hartholt KA, van Beeck EF, Polinder S et al. Societal consequences of falls in the older population: Injuries, healthcare costs, and long-term reduced quality of life. J Trauma 2011;71:748–753.
52. Bell CM, Urbach DR, Ray JG et al. Bias in published cost effectiveness studies: Systematic review. BMJ 2006;332:1–5.
53. Caro JJ, Briggs AH, Siebert U, Kuntz KM. Modeling good research practices—overview: A report of the ISPOR-SMDM Modeling Good Research Practices Task Force-1. Med Decis Making 2012;32:667–677.
54. Husereau D, Drummond M, Petrou S et al. Consolidated health economic evaluation reporting standards (CHEERS)—explanation and elaboration: A report of the ISPOR health economic evaluations publication guidelines good reporting practices task force. Value Health 2013;16:231–250.

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.