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Economic evaluations of fall prevention exercise programs: a systematic review

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► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bjsports-2022-105747).

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Accepted 20 September 2022
Published Online First 27 October 2022

Check for updates

To cite: Pinheiro MB, Sherrington C, Howard K, *et al*. *Br J Sports Med* 2022;**56**:1353–1365.

ABSTRACT

Objective To investigate cost-effectiveness and costs of fall prevention exercise programmes for older adults.

Design Systematic review.

Data sources Medline, Embase, Web of Science, Scopus, National Institute for Health Research Economic Evaluation Database, Health Technology Assessment database, Tufts Cost-Effectiveness Analysis Registry, Research Papers in Economics and EconLit (inception to May 2022).

Eligibility criteria for study selection Economic evaluations (trial-based or model-based) and costing studies investigating fall prevention exercise programmes versus no intervention or usual care for older adults living in the community or care facilities, and reporting incremental cost-effectiveness ratio (ICER) for fall-related outcomes or quality-adjusted life years (QALY, expressed as cost/QALY) and/or intervention costs.

Results 31 studies were included. For community-dwelling older adults (21 economic evaluations, 6 costing studies), results ranged from more effective and less costly (dominant) interventions up to an ICER of US$279 802/QALY gained and US$11 986/fall prevented (US$ in 2020). Assuming an arbitrary willingness-to-pay threshold (US$100 000/QALY), most results (17/24) were considered cost-effective (moderate certainty). The greatest value for money (lower ICER/QALY gained and fall prevented) appeared to accrue for older adults and those with high fall risk, but unsupervised exercise appeared to offer poor value for money (higher ICER/QALY). For care facilities (two economic evaluations, two costing studies), ICERs ranged from dominant (low certainty) to US$35/fall prevented (moderate certainty). Overall, intervention costs varied and were poorly reported.

Conclusions Most economic evaluations investigated fall prevention exercise programmes for older adults living in the community. There is moderate certainty evidence that fall prevention exercise programmes are likely to be cost-effective. The evidence for older adults living in care facilities is more limited but promising.

PROSPERO registration number PROSPERO 2020 CRD42020178023.

WHAT ARE THE FINDINGS?

⇒ Supervised fall prevention exercise programmes, delivered to older adults living in the community are likely to offer good value for money, particularly when delivered to 'older' old people (eg, aged 80+) and people with high fall risk.
⇒ The evidence for programmes delivered to older adults living in care facilities is more limited, but promising, highlighting the need for more studies in this setting.
⇒ The intervention costs summarised in this review should be interpreted with consideration of the type of exercise, duration, level of supervision and number of participants and can be used for planning the implementation of future programmes or future models investigating the value for money of such programmes.

HOW MIGHT IT IMPACT ON CLINICAL PRACTICE IN THE FUTURE?

⇒ This review findings provide support for a widespread implementation of fall prevention exercise programs for older people living in the community.

INTRODUCTION

One in three community-dwelling people aged over 65 years fall each year[1 2] with the rate of fall-related injuries increasing with age.[3] In aged care facilities, falls are a particular problem with at least 50% of residents falling each year.[4] Consequences of falls include fractures and brain injuries,[3] reduced quality of life,[5] fear of falling, loss of confidence and self-restricted activity leading to a reduction in physical function and social interactions.[6] The restriction of activities probably increases the risk of further falls by contributing to deterioration in physical capacity.

Exercise delivered as a single intervention is the most commonly investigated fall prevention intervention. Its effectiveness is supported by a recent Cochrane Review, which showed that exercise reduces the risk of falls by 23% in older adults living in the community.[7] Exercise interventions are effective when delivered in a group-based setting or individually. Programmes that include balance/functional training and multicomponent programmes that target both strength and balance appear to be particularly effective.[7 8] In aged care facilities, the effectiveness of exercise for preventing falls is less clear, with a 2018 Cochrane Review[9] showing low-quality evidence of no effect. However, a more

recent trial[10] has shown promising results, with a 55% reduction in falls from a strength and balance exercise programme.

Previous systematic reviews have summarised the evidence on the cost-effectiveness of fall prevention exercise programmes, but they focused on specific population subgroups, such as adults aged>80 years[11] or people with Parkinson's Disease,[12] or on fall prevention strategies more broadly rather than exercise as a single intervention.[13] To date, no reviews have summarised and critically appraised the evidence on the cost-effectiveness of fall prevention exercise programmes as a single intervention for older adults living in the community and aged care facilities. Previous reviews would not have included more recent studies as the latest search was conducted in 2018 and excluded partial economic evaluations (costing studies). Costing studies can provide useful information on intervention costs that are essential for implementation. Considering the scarcity of healthcare resources and the burden posed by falls to individuals and societies, a comprehensive up-to-date review summarising the value for money of fall prevention exercise programmes would contribute to evidence-based policy and decision-making.

The aim of this review was to summarise the evidence from economic evaluations and costing studies of fall prevention exercise programmes delivered to: (1) adults aged 60+ years living in the community; (2) adults aged 60+ years living in aged care facilities. The review questions were:

1. What is the cost-effectiveness and cost-utility of fall prevention exercise programmes?
2. What are the costs of developing and implementing fall prevention exercise programmes?

METHODS

This review was commissioned by the WHO Physical Activity Unit to inform the development of the WHO ACTIVE toolkits,[14] which will assist countries to tailor and implement the policy recommendations outlined in the Global Action Plan on Physical Activity 2018–2030.[15] This review may also support the updating of the WHO CHOICE modelling of cost-effective interventions for physical activity[15 16] as part of the wider programme of CHOICE work on non-communicable disease management and prevention.

We followed the guideline recommendations for conducting systematic reviews of economic evaluations for informing evidence-based healthcare decisions[17–19] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[20] The review protocol was prospectively registered (PROSPERO 2020 CRD42020178023).

Data sources

We searched the following specialised databases and registries, which contain records of full and partial economic evaluations from inception to July 2021 (online supplemental materials 1): the National Institute for Health Research Economic Evaluation Database (via Centre for Reviews and Dissemination (CRD) up to 2015), Health Technology Assessment database (via CRD), the Tufts Cost-Effectiveness Analysis Registry, Research Papers in Economics (via EconPapers) and EconLit (Ebsco). We also searched Medline (via Ovid) and Embase from inception to July 2021. In May 2022, all searches were updated, and additional searches were conducted from inception to May in Scopus and Web of Science. We reviewed the reference lists of included papers as well as other relevant systematic reviews such as Cochrane reviews[7 9] for relevant studies, and contacted experts in the field.

Eligibility

Type of study

We included full (cost-effectiveness, cost-utility and cost-benefit analysis) and partial (cost analysis) economic evaluations of fall prevention exercise interventions in older adults living in the community and aged care facilities to prevent falls. Both trial-based and model-based economic evaluations were included. We classified studies as trial-based analyses where all the information used to perform the economic evaluation was obtained from the trial to determine clinical effectiveness. All economic evaluations that relied on external information as a source of input for the analyses were classified as model-based, even if they only modelled the intervention using the effectiveness trial parameters, such as duration and sample size. No restrictions were applied on language, publication date or country and only peer-reviewed manuscripts and policy-relevant reports from trustworthy organisations were included.

Participants

Studies were included if they involved participants 60 years of age or older living in the community or an aged care facility.

Intervention

We only included studies where the intervention of interest was exercise that aimed to prevent falls. We excluded multifaceted interventions, where exercise was only a component of a broader intervention, as in this type of study it is not possible to quantify the effects of exercise alone.

Comparator

We included studies where an exercise intervention was compared with 'usual care' (ie, no change in usual activities), no intervention or a control intervention (ie, an intervention that is not thought to reduce falls, such as general health education, social visits, very gentle exercise or 'sham' exercise not expected to impact on falls).

Main outcomes

The health outcomes of interest were fall-related outcomes, including number of falls (or fall-related injuries, fractures or hospitalisation), and number of individuals with falls (or fall-related injuries, fractures or hospitalisation). The main health economic outcomes were incremental cost-effectiveness ratio (ICER) expressed as the incremental cost per fall prevented (or per fall-related outcomes) or incremental cost per quality-adjusted life year (QALY) gained by the intervention group compared with the comparator. Secondary outcomes were costs, such as total costs, intervention costs, health service utilisation costs, community services costs and out-of-pocket costs.

Study selection and data extraction

Two reviewers independently screened all titles and abstracts, followed by full texts, and disagreements were solved by consensus or discussion with a third reviewer. Data extraction was conducted by an experienced reviewer and all data were checked by a second reviewer. The following information was extracted into a standardised data extraction form: authors, year, journal, country, type of economic analysis, study sample characteristics, sample size, intervention and comparator description, measure of effectiveness (in terms of falls and QALYs), economic analysis perspective, type of currency, price year, time horizon, discounting, costs (total, intervention, health service utilisation, community services, out of pocket, other), ICER, sensitivity

analysis and author's conclusion. Data were extracted from the included study as well as from any other relevant publication cited in the study, such as an economic evaluation protocol or the main trial results.

We used elements of a framework for classifying physical activity programmes and services for older adults that we developed for our previous reviews for WHO[21] to guide our extraction of participant characteristics and intervention description data. We used the Prevention of Falls Network Europe taxonomy to classify the exercise programmes in the included studies on the basis of the primary exercise category and noted the presence of additional, secondary, exercise categories.[22] The programmes were classified as primarily involving the following exercise categories: (1) gait, balance, coordination and functional task training (referred to as 'balance and functional exercises' for simplicity); (2) strength/resistance training (including power training, using resistance so referred to as 'resistance exercises'); (3) flexibility; (4) three-dimensional (3D) exercise (with tai chi or dance subcategories); (5) general physical activity (walking programmes); (6) endurance; (7) other kinds of exercise. The taxonomy allows for more than one type of exercise to be delivered within a programme. We classified programmes as multicomponent if two or more components were given equal emphasis in the intervention.

Risk of bias

Risk-of-bias assessment was conducted by two independent reviewers using the Consensus on Health Economic Criteria list (CHEC-list, online supplemental material 2)[23] and any discrepancies were discussed and reviewed by a third reviewer. We created a modified version of the CHEC-list to assess the risk of bias of the costing studies (online supplemental material 3) and the final version was reviewed and approved by three authors. When rating the studies using the CHEC-list, we considered the information provided in the included study as well as from any other relevant publication cited in the study, such as an economic evaluation protocol or the main trial results.

We also rated all model-based economic evaluations considering three additional items not covered by CHEC-list items but identified by authors as relevant to the quality of the studies in the context of the present review: (1) Was the effectiveness measure used appropriate to the modelled intervention and population? Did the study that contributed the effectiveness estimate investigate a population and exercise intervention with similar characteristics to that being modelled? (2) Did the model appropriately consider attenuation of effectiveness on falls, post intervention? Was any evidence used to support the continued effectiveness of the intervention beyond the trial duration? (3) Did the study report intermediate measures or use a 'stepped approach' to report the results of each step of the model to allow understanding of the impact of each step on the overall results?

For the trial-based economic evaluations, we considered the methodological quality of the effectiveness trial used to conduct the economic evaluation by using the Physiotherapy Evidence Database (PEDro) scale.[24 25] The PEDro scores publicly available in the PEDro database (www.pedro.org.au) were used.

Strategy for assessing the certainty of economic evaluations for WHO decision-making

We developed a rating scale to assess the overall certainty of the model-based economic evaluations based on the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) principles[26] as well as previous recommendations for assessing the certainty of evidence from modelling studies.[27] The risk-of-bias assessment items (extended CHEC-list) and the three additional items were integrated in our certainty of evidence assessment and the following domains were considered for model-based economic evaluations: (A) quality of model reporting, (B) certainty of model inputs, (C) credibility of model, (D) certainty of model outputs, (E) directness of model (online supplemental material 4).

For the trial-based economic evaluations, in addition to the risk-of-bias assessment (CHEC-list items), we considered the methodological quality of the effectiveness trial used as input for the economic evaluation (PEDro items 2, 4 and 8) to assess the certainty of the evidence (online supplemental material 5). The following domains were considered for trial-based economic evaluations: (A) quality of trial-based economic evaluation reporting, (B) credibility of the clinical trial, (C) credibility of economic evaluation, (D) certainty of economic evaluation results, (E) applicability. Each domain was rated as 'good', 'fair' or 'poor' and the level of certainty of each economic model for WHO decision-making was rated as high, moderate, low or very low considering the ratings for the domains.

Strategy for data synthesis

Results were not pooled as the studies were heterogeneous in their intervention, methods, data and context. Instead, we presented a narrative synthesis of the findings from included studies. Summaries of effect size, cost-effectiveness and costs were reported for each study (as available). Summary tables and figures are also provided. We used an arbitrary willingness-to-pay threshold of US$100 000 per QALY gained and US$4000 per fall prevented to assist with the interpretation of results.[28]

Studies reported costs in different currencies and from different years. To enable comparison of findings, we expressed monetary values in two ways: (1) by year and currency as reported by the included study, (2) converted to 2020 US$. We initially inflated the costs to year 2020 using the inflation rate for each country according to inflation rates from theOrganisation for Economic Co-operation and Development (OECD) database (https://data.oecd.org/price/inflation-cpi.htm). Then we transformed the costs in respective currencies of 2020 into US$ using purchasing power parity conversion factors for 2020 (https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm).

RESULTS

The electronic search retrieved 6882 records and hand searching identified two additional eligible records. A total of 31 records were included in this review (online supplemental figure 1). Most studies investigated older adults living in the community (n=27), followed by older adults living in aged care facilities (n=4). Results are presented below for each of these groups. The records excluded at full-text screening and the reasons for exclusion are presented in online supplemental material 6.

Fall prevention exercise targeted at older adults living in the community

Question 1: What is the cost-effectiveness and cost-utility of fall prevention exercise programs?

Study characteristics

We found a total of 20 economic evaluations reported in 21 articles, 9 trial-based[29–37] and 12 model-based,[38–48]

investigating the cost-effectiveness of 29 individual fall prevention exercise programmes for older adults living in the community (online supplemental table 1). Two articles reported the results of the same trial-based economic evaluation.[29 37] All economic evaluations were conducted in high-income countries (eg, Australia, Canada, Germany, New Zealand and the USA), see online supplemental table 2. Within the trial-based economic evaluations, balance/functional exercise was the type of exercise most frequently investigated (n=4), followed by multicomponent exercise (n=3) and tai chi (n=2). Within the model-based analyses, balance/functional exercise was also the most frequently investigated type of exercise (n=9), followed by tai chi (n=5), exercise type not specified (n=5) and multicomponent (n=1) (online supplemental table 3).

Within the trial-based economic evaluations, four studies recruited participants from the general population,[31 34–36] and five studies recruited people with a higher fall risk, mobility impairment (n=4)[29 32 33 37] or older adults with recent hospital admission (n=1).[30] All studies evaluated fall prevention, and were powered for falls, but two studies did not find an effect of the exercise programme on falls.[30 31] These studies are presented in online supplemental tables, but were excluded from the summary tables and figures, which were used to draw conclusions about the value for money of the interventions. Online supplemental table 5 presents a summary of the control group intervention investigated in the trial-based economic evaluations.

Within the model-based economic evaluations, models were applied to the general population (n=9),[39–43 45 47–49] a population with high fall risk (n=2)[44 46] and one study did not report the health status of the population investigated.

A description of the approach to the model-based analysis for each economic evaluation (n=12) is described in online supplemental table 4. Most studies used an effectiveness estimate derived from a systematic review and/or meta-analysis (n=9) and used parameters that were considered relevant and appropriate for the population investigated (n=7) or to some extent relevant to the population of interest (n=5). Studies varied in the consequences of falls considered, (eg, hospitalisations only,[40] versus range of consequences for example, injuries, fractures and death) and the assumptions made between falls and injury (eg, linear relationship) and effectiveness of exercise programmes on falls and fall-related injuries (eg, equivalent effect). All studies assumed no health gains beyond the intervention duration.

A summary of results for both trial and model-based economic evaluations is presented in online supplemental table 6 and figures 1 and 2). A detailed description of the methods and findings is included in online supplemental table 7 and a description of cost items and valuation sources used in the studies is provided in online supplemental table 8. The time horizon varied from 6 to 24 months for trial-based evaluations and from 12 months to lifetime for model-based evaluations. Most trial-based evaluations used a healthcare perspective (n=6), followed by intervention payer (n=2) and hospital (n=1). Similarly, most model-based evaluations used a healthcare perspective (n=8), followed by third-party payer (n=3) and societal (n=1).

Risk of bias and certainty of the evidence

Overall, the CHEC-list scores ranged from 11 to 17 out of 19 for trial-based analyses and from 10 to 17 out of 20 for the model-based analysis (online supplemental table 9). Limitations in the economic

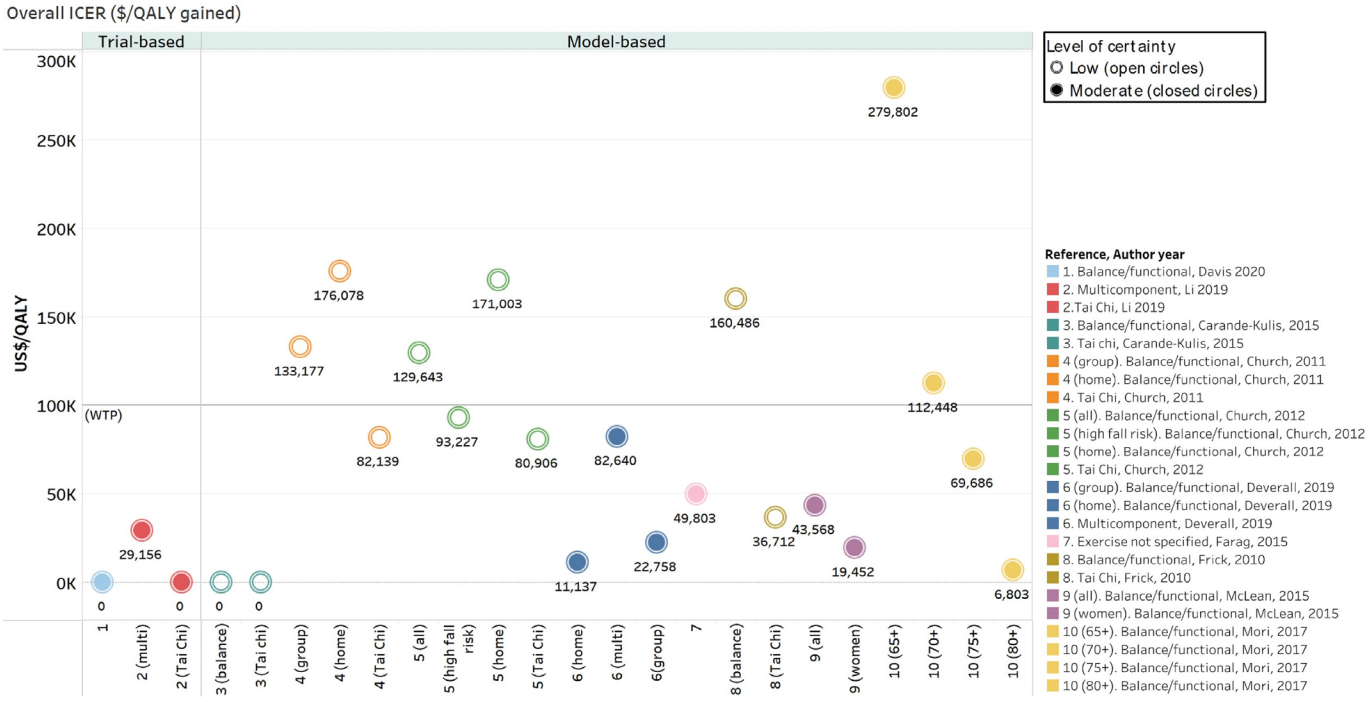

Figure 1 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per quality-adjusted life year (QALY) gained from economic evaluations of fall prevention exercise programmes for older adults living in the community. Results are presented separately for model-based and trial-based analyses. Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

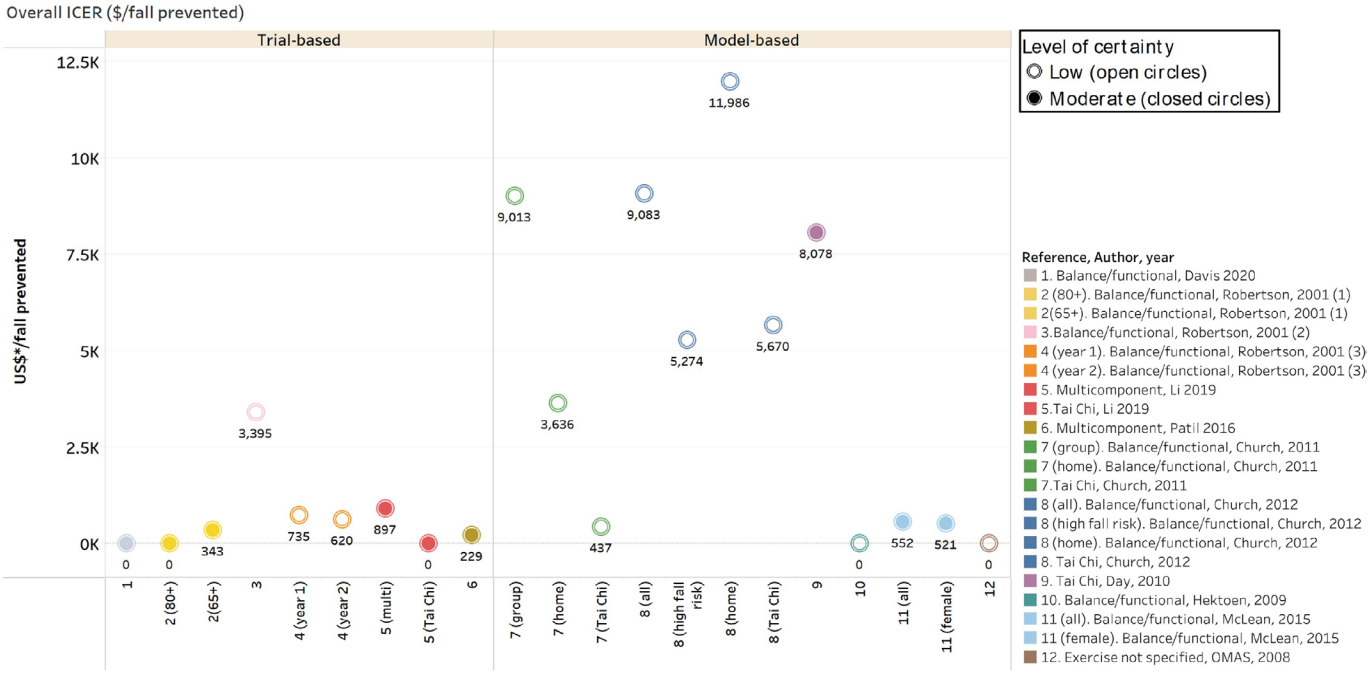

Figure 2 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per fall prevented from economic evaluations of fall prevention exercise programmes. *Costs are expressed as 2020 US$. Results are presented separately for model-based and trial-based analyses. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

evaluations included: limited uncertainty analyses, conclusions not supported by the findings, lack of identification of all relevant costs for both alternatives, poor description of competing alternatives and of the structural assumptions and the validation methods of the model (only relevant for model-based analysis).

Online supplemental table 10 presents the findings for the additional questions on the quality of the models, and online supplemental table 11 presents the author's conclusions and detailed reviewers' comments on the approach to the economic evaluations of fall prevention exercise programmes. Overall, studies selected appropriate and population relevant measures of effectiveness (9 out of 11) and appropriately considered attenuation of effect post intervention (7 out of 8, n=3 models only modelled the trial duration). However, most studies failed to explore all the relevant parameters in sensitivity analyses, did not report all parameters used in the model as well as their sources and only reported results for the end of the time horizon investigated instead of presenting intermediate measures which would enhance the interpretability of the findings.

Our GRADE style rating for trial-based evaluations ranged from low (n=3 studies investigating 3 interventions) to moderate level of certainty (n=6 studies investigating 6 interventions), indicating that we have limited-to-moderate confidence that the outputs from the trial-based economic evaluations are reliable for decision-making (online supplemental table 6 and material 7). The model-based studies (n=12) investigated a total of 20 interventions, and our GRADE style rating ranged from low (n=7 studies investigating 12 interventions) to moderate level of certainty (n=6 studies investigating 8 interventions), indicating that we have limited-to-moderate confidence that the outputs from the models are reliable for decision-making (online supplemental table 6 and material 8).

Cost-effectiveness results

The included studies reported ICERs for five outcomes: QALY, fall, fall-related injuries, fall-related fractures and fall-related hospitalisation. An overview of ICERs expressed as additional cost per QALY gained is presented in figure 1. Two trial-based and eight model-based evaluations reported QALYs for a total of two comparisons as some studies investigated more than one exercise group or reported results for subgroups. The results varied, ranging from the intervention being more effective and less costly (dominant) in four comparisons to an incremental cost of US$279 802 (2020 US$) per QALY gained. When considering an arbitrary willingness-to-pay threshold of US$100 000/QALY gained,[28] most results (17 out of 24) were considered to be cost-effective and 11 of these 17 results were rated as moderate quality. Overall, the studies with moderate certainty showed better cost-effectiveness (lower ICERs).

A total of 12 studies reported results for falls (6 trial-based and 6 model-based) for 21 comparisons (figure 2). The findings from studies investigating falls found ICERs ranging from the intervention being more effective and less costly (dominant) in five comparisons, to US$11 986 per fall prevented (figure 2). Overall, 15 out of 21 results had ICERs below US$4000 per fall prevented and 8 of these were rated as moderate quality.

Fewer studies investigated other fall-related outcomes (n=8 studies, 4 model-based and 4 trial-based, investigating 16 comparisons) and the results for these outcomes are displayed in online supplemental figure 2. The results also varied and suggest a trend of increased ICER for more serious fall-related outcomes, from fall-related injury (ICER ranging from dominant to US$1430) to fracture (ICER ranging from US$14 031 to US$125 951) and hospitalisation (ICER ranging from US$9466 to US$403 927). Most comparisons were rated as moderate quality (10 out of 16).

Post-hoc analyses

Several post-hoc analyses were undertaken to explore the cost-effectiveness results according to relevant characteristics of the studies. Stratified by the type of exercise, the results for tai chi,

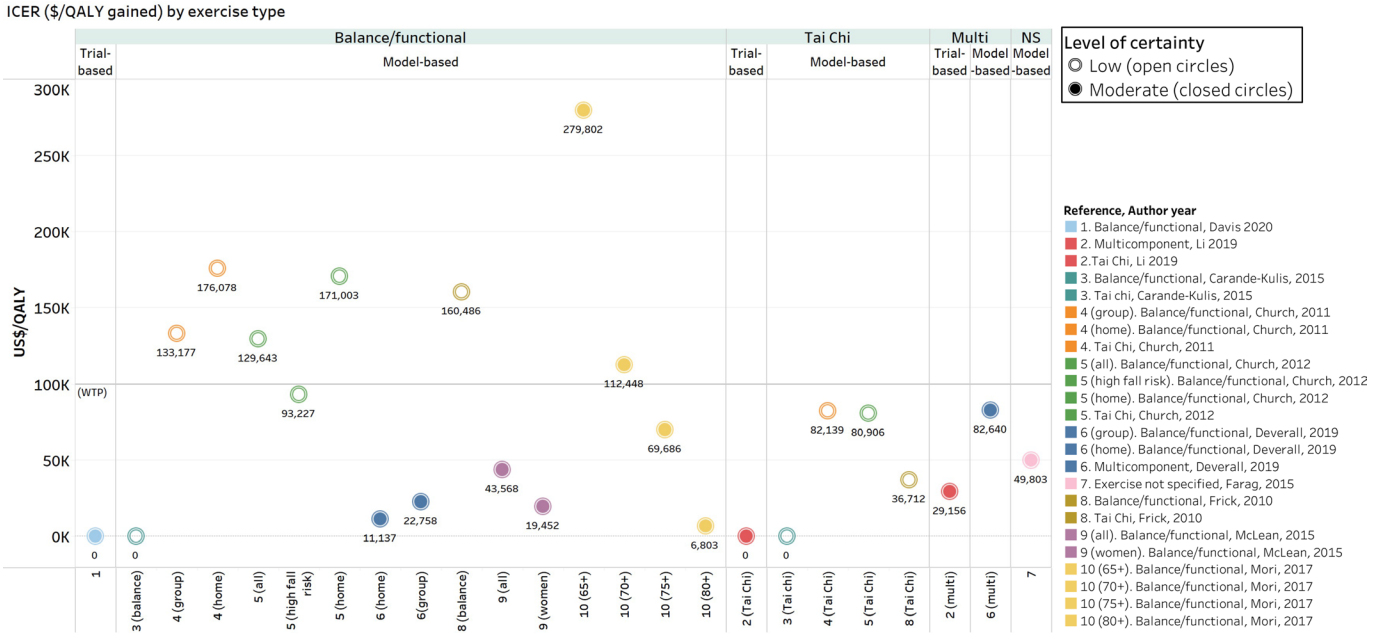

Figure 3 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per QALY gained from economic evaluations of fall prevention exercise programmes according to exercise type. Multi, multicomponent; NS, exercise type not specified. Results are presented separately for model- and trial-based analyses Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

multicomponent exercise and unspecified exercise programmes were below the willingness-to-pay threshold of US$100 000/QALY gained. Within the studies investigating balance/functional exercise, 9 out of 16 were below the threshold of US$100 000/QALY gained (figure 3). Overall, the studies with moderate certainty showed better cost-effectiveness (lower ICERs). For falls prevented, no specific pattern could be identified therefore it was not clear whether a specific type of exercise offered better value for money (figure 4).

The level of supervision of exercise programmes (supervised; unsupervised; mix of unsupervised and supervised sessions) was found to impact on results. Overall, there

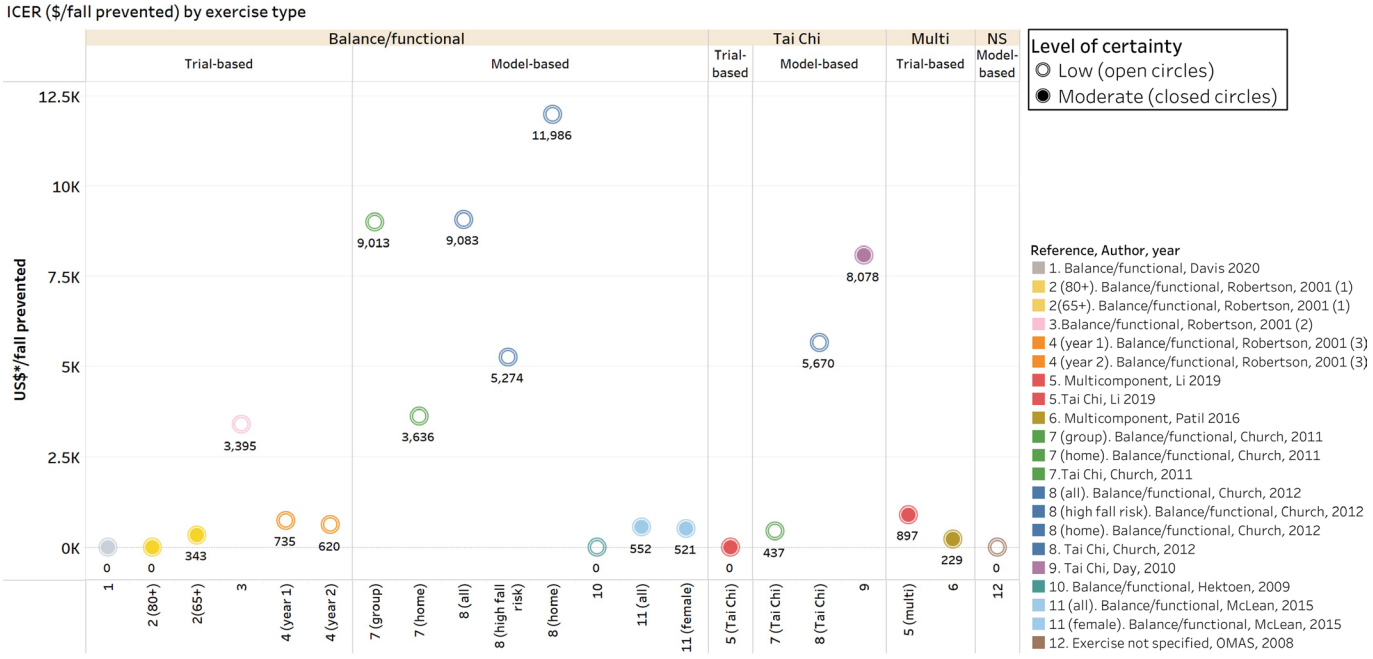

Figure 4 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per fall prevented from economic evaluations of fall prevention exercise programmes according to exercise type. Multi, multicomponent; NS, exercise type not specified. Results are presented separately for model-based and trial-based analyses *Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

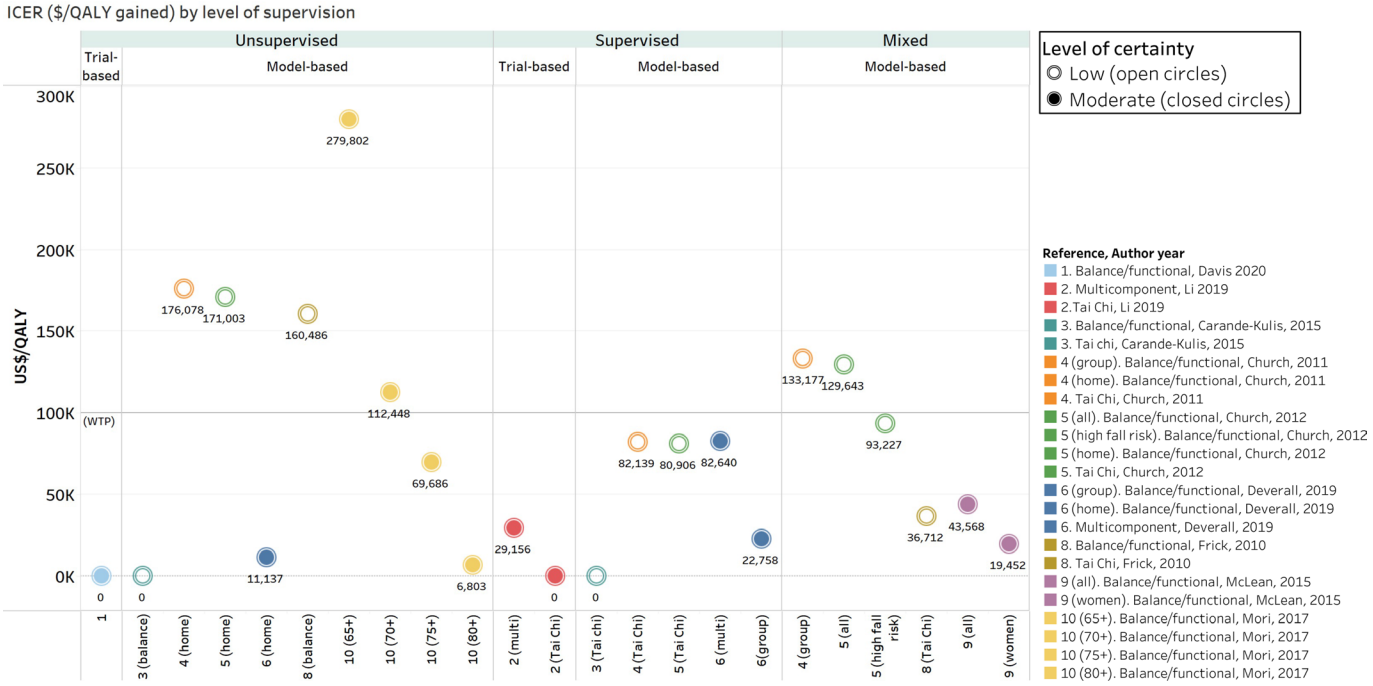

Figure 5 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per QALY gained from economic evaluations of fall prevention exercise programmes according to level of supervision. Results are presented separately for model-based and trial-based analyses Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

was a trend for unsupervised exercise to have higher ICER for QALY (5 out of 10 comparisons below US$100 000 threshold), whereas all comparisons for supervised exercise were below the US$100 000 threshold (figure 5). No specific pattern was found when fall outcome was considered (figure 6).

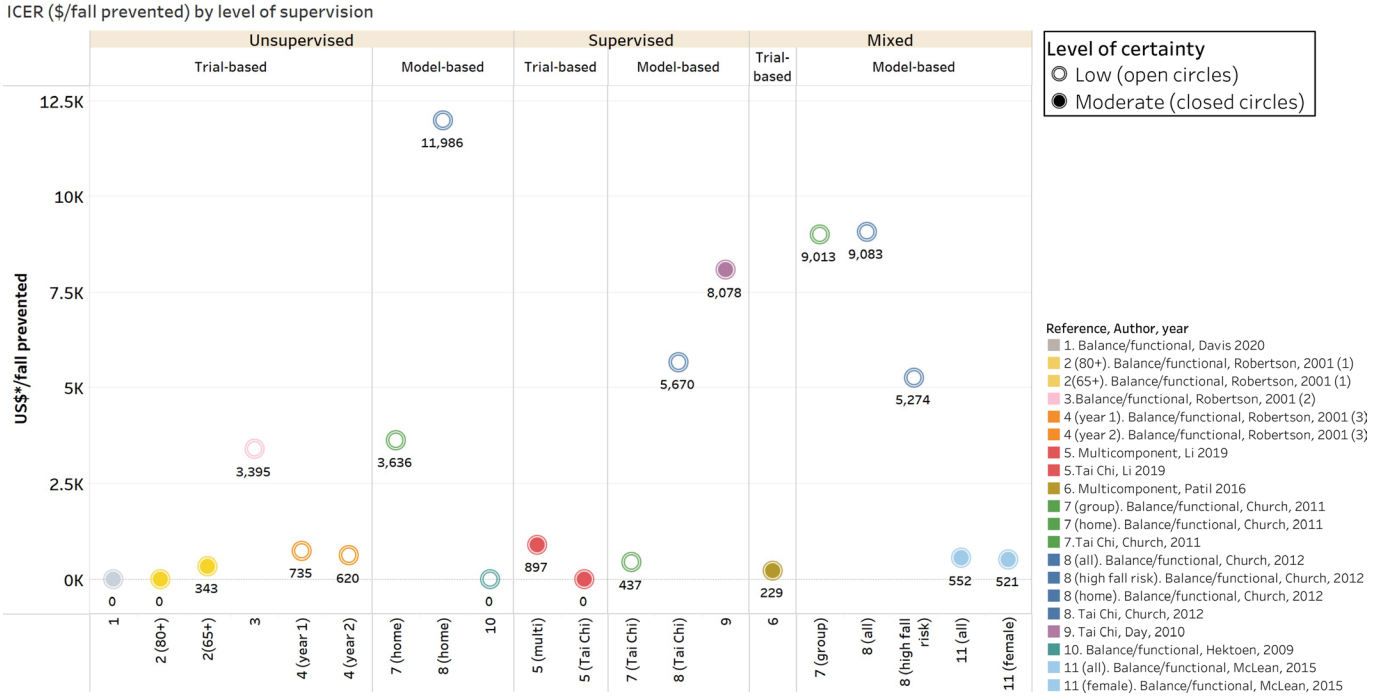

Figure 6 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per fall prevented from economic evaluations of fall prevention exercise programmes according to level of supervision. Results are presented separately for model-based and trial-based analyses. *Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

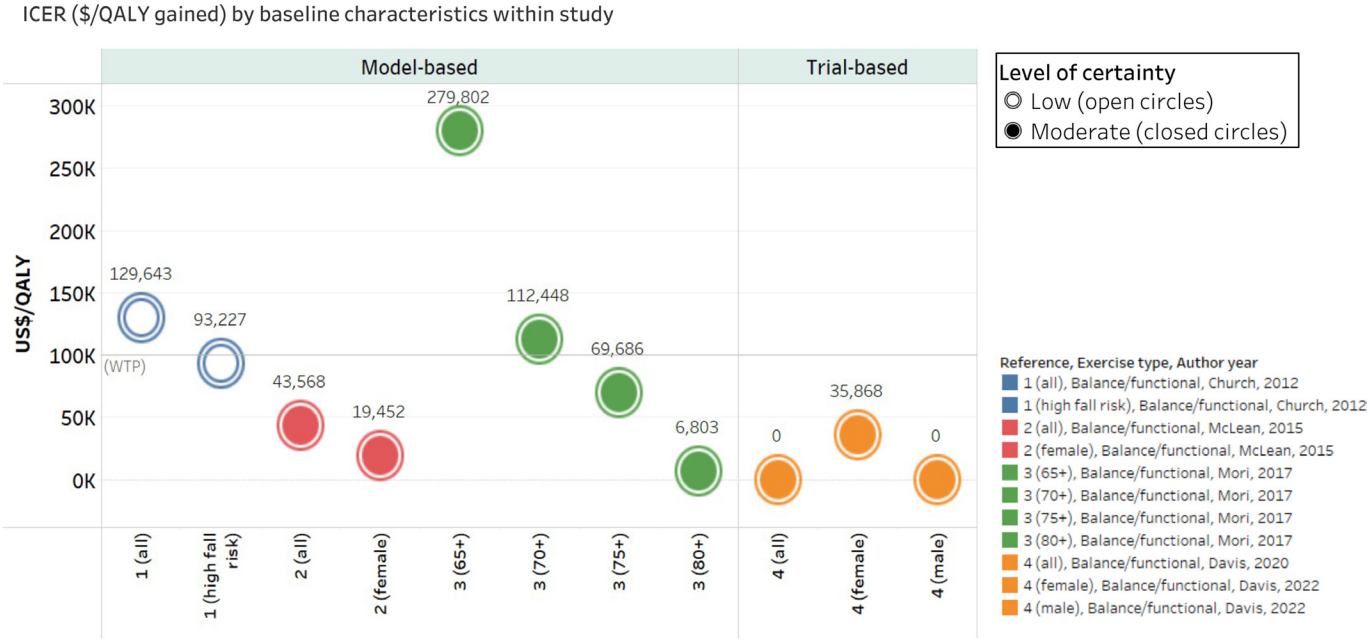

Figure 7 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per quality-adjusted life year (QALY) gained from economic evaluations of fall prevention exercise programmes according to baseline characteristics explored within the study. Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

Lastly, when considering participants' baseline characteristics (general population, older age (as per included study definition), female, high fall risk) no specific pattern was found for QALY (online supplemental figure 3). However, for fall prevention, higher ICERs were found for the general population, suggesting that the intervention offers better value for money for the other subgroups (online supplemental figure 4). There were six studies that reported results separately for age, fall risk and sex. When these characteristics were explored within the studies (differences between the subgroups were not tested statistically), the ICERs for older and high fall risk were always lower (indicating better cost-effectiveness) for QALY (figure 7) and fall outcomes (figure 8).

Question 2: What are the costs of developing and implementing fall prevention exercise programs for older adults living in the community?

We found five studies that estimated the costs of developing and implementing fall prevention exercise programmes in the community (online supplemental table 1).[50–54] The results of one study were reported in two papers.[52 55] All studies were conducted in high-income countries and the geographical location is presented in online supplemental table 2.

The costing studies investigated balance/functional exercise (n=2), multicomponent (n=1), tai chi (n=1). One study did not specify exercise type. The risk-of-bias ratings for the costing studies varied, ranging from 5 to 12 out of 15 (median score=6, online supplemental table 13).

Overall, intervention costs were poorly reported (online supplemental table 12). The included studies (n=24) investigated a total of 34 exercise programmes and total intervention costs, and cost breakdown was only available for 14 (41%) programmes. Total costs were only reported for 17 exercise programmes (50%). The intervention cost per person per week varied, ranging from US$0.40 to US$83 (table 1). No pattern could be found for intervention costs according to type of exercise (table 1). Online supplemental table 12 provides a detailed description of total cost, cost per item, cost in the reported currency and year, as well as costs translated to 2020 US$, and cost per week for each of the exercise programmes.

Fall prevention exercise targeted at older adults living in aged care facilities

Question 1: What is the cost-effectiveness and cost-utility of fall prevention exercise programs?

Study characteristics

We found one trial-based[10] and one model-based[56] economic evaluation investigating the cost-effectiveness of fall prevention exercise programmes in aged care facilities (online supplemental table 1). The studies were conducted in high-income countries (Australia and the USA) and investigated multicomponent and tai chi exercise programmes. Both programmes were fully supervised by an instructor and conducted in groups. Both economic evaluations had a time horizon of 12 months but differed in the perspective taken, that is, health service perspective[10] and societal perspective[56] (table 2 and online supplemental table 4).

Risk of bias and certainty of the evidence

The risk-of-bias rating of the economic evaluations was 9 out of 20 for the model-based evaluation and 17 out of 19 for the trial-based economic evaluation (online supplemental table 9). Online supplemental tables 10 and 11 presents detailed information about the quality of the economic evaluations.

Our GRADE style rating found a moderate level of certainty for the trial-based evaluation (online supplemental material 7), indicating moderate confidence that the outputs are reliable for decision-making. A low level of certainty was found for the model-based analysis indicating that we have limited confidence

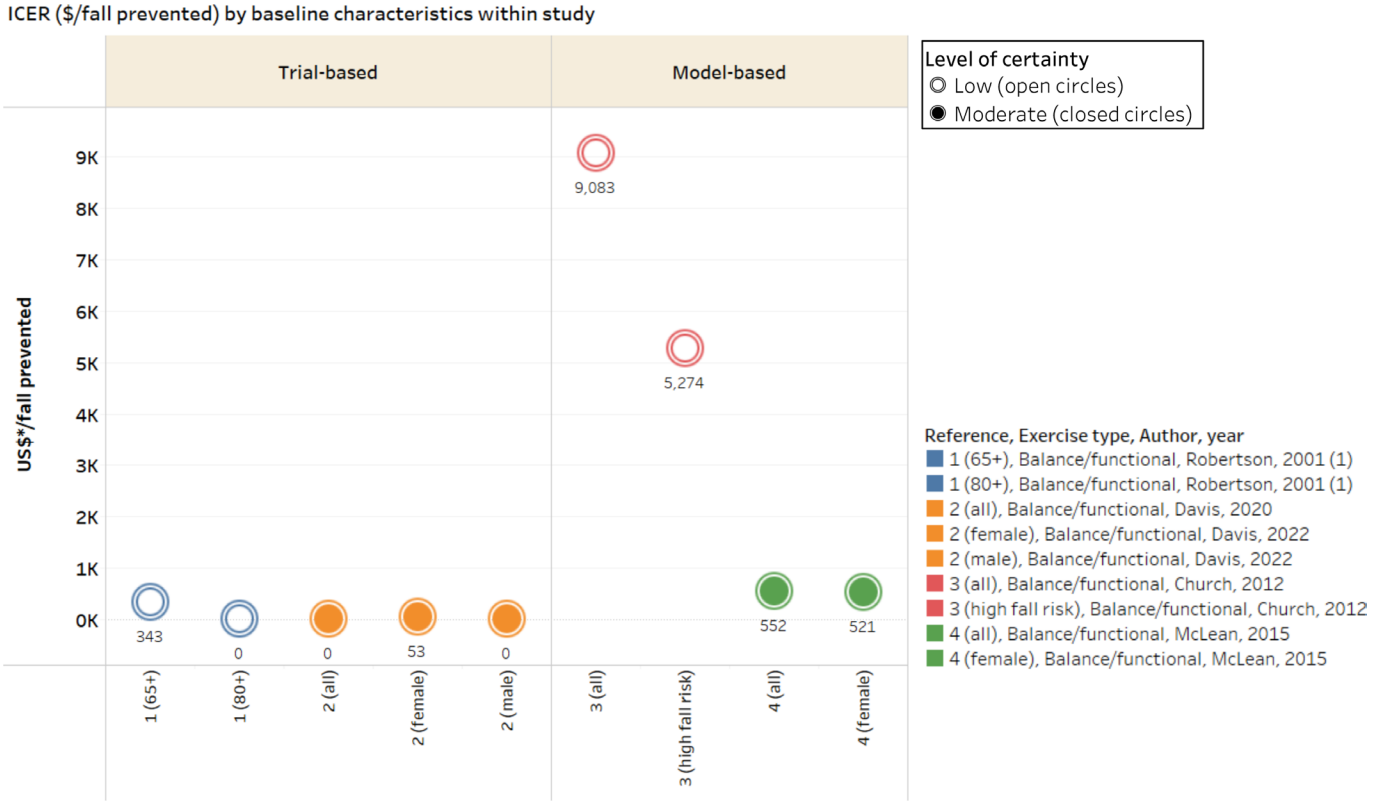

Figure 8 Incremental cost-effectiveness ratios (ICERs) expressed as additional cost per fall prevented from economic evaluations of fall prevention exercise programmes according to baseline characteristics explored within the study. *Costs are expressed as 2020 US$. Dominant interventions (ie, more effective and less costly) are shown on the zero line. Same colours and numbers indicate same study. Closed circles indicate moderate level of certainty and open circles indicate low level of certainty. Uncertainty intervals are not displayed as most studies did not report it.

that the outputs from this model are reliable for decision-making (online supplemental material 8).

Cost-effectiveness results

Both studies investigated fall-related outcomes (fall and injurious fall). The trial-based evaluation that investigated the multicomponent exercise programme found ICERs of US$35/fall prevented and US$56/injurious fall avoided. The study that modelled the tai chi programme found that the intervention was less costly and more effective (dominant) (table 2).

Question 2: What are the costs of developing and implementing fall prevention exercise programs for older adults living in aged care facilities?

In addition to the two economic evaluations,[10 56] we also found two costing studies,[57 58] which were also conducted in a high-income country (the USA) and investigated multicomponent exercise programmes. The CHEC-list Score for the costing studies was low and rated as 4 and 6 out of 15 (online supplemental table 13).

All four studies included in this review reported intervention costs, but none of them reported the total costs as well as the breakdown of the cost items contributing to the total cost (online supplemental table 12). Only two studies reported intervention cost per person per week or provided enough data to allow its calculation and they reported a cost of US$3 and US$9 per person per week to run the exercise in the aged care facility (table 3).

DISCUSSION

There are a considerable number of economic evaluations of fall prevention exercise programmes for people living in the community (n=20, reported in 21 articles), but none were conducted in low-income or middle-income countries. Overall, there was heterogeneity in the economic analyses investigated, making direct comparisons difficult. The results varied, with ICER estimates ranging from dominant (more effective and less costly) to as high as US$279 802 per QALY gained and US$11 986 per fall prevented. A considerable proportion of the interventions (17 out of 24, 71%) had an ICER below a willingness-to-pay threshold of US$100 000 per QALY gained. The level of certainty varied between low and moderate, but there was a considerable number of studies with moderate level of certainty (n=11). These results suggest that fall prevention exercise programmes probably offer good value for money depending on one's willingness to pay, particularly for 'older' old people (aged 80+ years) and those with high fall risk. There was a trend for more favourable results for supervised exercise. In contrast, there are few economic evaluations (n=2) investigating fall prevention exercise programmes for older adults living in aged care facilities. The results of these economic evaluations are promising, with relatively low ICERs for fall avoided (dominant and US$35/fall avoided) and moderate level of certainty for the trial-based analysis. None of the included studies conducted in care facilities investigated QALYs. The overall evidence in this setting is less clear, and more high-quality trial-based and model-based analyses are needed. The intervention costs varied across the included economic analyses

Table 1 Summary of results of the intervention costs of fall prevention exercise programs for older adults living in the community

Author/country (income)	Intervention name	Duration/frequency (range)	Supervision/supervised sessions, n, (who delivered)	Location (who with)	US$*/wk/person (median across studies, IQR (range))
Balance/functional					
Davis *et al*[29], Canada (HI)†; Davis *et al*[37], Canada (HI)† Robertson *et al*[34] (1), New Zealand (HI)*; Robertson *et al*[36] (2), New Zealand (HI)†; Robertson *et al*[35] (3), New Zealand (HI)†; Hektoen *et al*[44], Norway (HI)†; Church *et al*[49], Australia (HI)‡; Church *et al*[39], Australia (HI)‡; Deverall *et al*[41], New Zealand (HI)‡; Frick *et al*[43], USA (HI)‡, Mori *et al*[47], USA (HI)‡	Otago exercise programme	52 wks 3 times/wk plus walking 2–3 times/wk	Unsupervised/4–5 (health professional or trained exercise leader)	Home (individual)	US$12, US$8 to US$17 (min: US$7, max: US$83)
Deverall *et al*[41], New Zealand (HI)‡	Peer-led exercise programme	52 wks 1 time/wk	Supervised/52 (volunteer)	Community venue (group size NR)	US$6
Church *et al*[49], Australia (HI)‡; Church *et al*[39], Australia (HI)‡	Group-based exercise	26 wks 3 times/wk	Mixed/52 (personnel NR)	Community venue (group size NR): 2 times/wk Home (individual): 1 time/wk	US$40
McLean *et al*[45], Australia (HI)‡	'NoFalls' programme	15 wks 7 times/wk	Mixed/15 (health professional)	Community venue (group 15): 1 time/wk Home (individual): 6 times/wk	US$3
Multicomponent					
Patil *et al*[33], Finland (HI)†	Supervised group training and home exercise programme	104 wks 4–5 times/wk	Mixed/156 (health professional)	Community venue (group 10–20): 2 times/wk (Year 1), 1 time/wk (Year 2) Home (individual): 3 times/k	US$0.40
Li *et al*[32], USA (HI)†	Multimodal exercise	24 wks 2 times/wk	Supervised/48 (trained exercise leader)	Community venue (group 9–21)	US$44
Deverall *et al*[41], New Zealand (HI)‡	Commercially provided exercise programme	52 wks Frequency NR	NR	Community venue (group size NR)	US$23
Tai chi					
Li *et al*[32], USA (HI)†; Day *et al*[40], Australia (HI)‡; Carande-Kulis *et al*[38], USA (HI)‡; Church *et al*[49], Australia (HI)‡, Church *et al*[39], Australia (HI)‡	Tai chi classes (including 'Tai Ji Quan: Moving for Better Balance')	24–26 wks 2–3 times/wk	Supervised/48–78 (trained exercise leader)	Community venue (group 9–12)	US$45, US$31–50 (min: US$2, max: US$53)
Frick *et al*[43], USA (HI)‡; Li *et al*[54], USA (HI)§	Group and home tai chi	15–48 wks 7 times/wk	Mixed/30–96 (trained exercise leader)	Community venue (group size NR): 2 times/wk Home (individual): 5 times/wk	US$8 (min: US$2, max: US$14)
Exercise type not specified					
Farag,[42] (2), Australia (HI)‡	Public health programme	NR	NR	NR	US$1184¶ (mean cost/participant for the entire programme)
Ontario Medical Advisory Secretariat,[46], Canada (HI)‡	Long-term exercise programme	>24 wks Frequency NR	NR	NR	US$3

This table only includes studies where the intervention was powered for falls and had a significant impact on falls. Results for model-based, trial-based and costing studies are presented together. Iliffe *et al*[52] (costing study) was not powered for falls and they did not find an effect on falls and therefore results are not presented in this table (balance and functional). Dangour *et al*[51] (costing study) did not find an effect on falls and therefore results are not presented in this table (balance and functional). Kemmler *et al*[53] (costing study) did not find an effect on falls and therefore results are not presented in this table (multicomponent). Farag *et al*[42] (1) (trial-based study) did not find an effect on falls and therefore results are not presented in this table (multicomponent). Haas[31] (trial-based study) did not find an effect on falls and therefore results are not presented in this table (tai chi). Mulrow *et al*[58] (costing study) was not presented in this table as the intervention was not aimed to increase falls and did not impact on falls. Church *et al*[39 49] used the same cost estimates and therefore only one estimate is represented in this table. Mori *et al*[47] and Carande-Kulis *et al*[38] used the same cost estimates and therefore only one estimate is represented in this table. Buchner *et al*[50] did not present the appropriate data required to calculate costs and has therefore been omitted from this table (multiple exercise types).
*In 2020 US$.
†Indicates trial-based economic evaluation.
‡Indicates model-based economic evaluation.
§Indicates costing study.
¶Where cost/participant/week was not available, the reported mean cost/participant for the entire programme has been indicated.
**Number of participants engaging in the intervention not reported therefore it was not possible to calculate the cost per person per week.
NR, not reported; wk(s), week(s).

and are similar to costs found in previous reports of fall prevention exercise.[59]

Implications for clinicians and policy-makers

Although our results suggest that exercise programmes may offer better value for money for specific subgroups ('older' old people, people with higher fall risk) and this information could inform budget allocation, we argue that fall prevention exercise should be offered to all older adults given its proven benefits for fall reduction.[7] Although a trend was found for multicomponent and tai chi exercises and supervised programmes to offer better value for money than balance and functional exercise and unsupervised programmes, these results should be interpreted with caution. Therefore, policy-makers and managers considering funding exercise programmes should choose the exercise type and supervision level according to their context and budget.

We have selected an arbitrary willingness-to-pay threshold of US$100 000 per QALY gained to facilitate the interpretation of findings. Although this threshold has been commonly referenced in the US literature,[28] whether an intervention is cost-effective

Table 2 Summary of results of the trial and model-based economic evaluations investigating fall prevention exercise programs in older adults living in aged care facilities

Author/country (income)/campaign	Perspective/horizon	Population	Exercise description*	US$†/QALY, 95% CI or UI	US$†/fall prevented, 95% CI or UI	Level of certainty‡
Trial-based						
Balance/functional						
Hewitt *et al*[10], Strength and balance exercise programme	Healthcare system 12 months	► Care facilities residents ► 65% female	Strength and balance exercises Progressive training: 2 days/wk for 60 min/session over 26 wks Maintenance phase: 30 /min session over 26 wks	NR	US$22/fall prevented (95% CI −380 to 418) US$56/injurious fall avoided (UI NR)	Moderate
Model-based						
3D (tai chi)						
Wilson *et al*[56], Tai chi	Societal 12 months	► Care facilities residents with average fall risk ► % female: NR	Tai chi 2 days/wk for 60 min/session over 52 wks	NR	Dominant (net cost-saving: US$1834)	Low

Dominant indicates that the intervention was less costly and more effective.
*Salient details only; a full description of each intervention is available in online supplemental table 1
†In 2020 US
‡Overall judgement of certainty of each economic model for WHO decision-making according to a GRADE style rating (see online supplemental material 12 for more details).
NR, not reported; QALY, quality-adjusted life year; UI, uncertainty interval; wk(s), week(s).

or not depends on the decision-maker's willingness to pay. Decision-makers considering implementing a fall prevention exercise programme should also take into account the additional benefits of physical activity for overall health[60] that were not included in the economic evaluations, low risk as well as the ease of implementation of the intervention (ie, no sophisticated equipment required and no need for the highly specialised workforce).

The overview of the intervention costs presented in this review should be interpreted in the context of the duration of the exercise programme, level of supervision and number of participants. Policy-makers and governments considering the implementation of a fall prevention exercise programme can use this information to inform their budget and implementation planning. The intervention cost information can also be used as an input for future model-based analyses.

None of the included studies were conducted in low-income and middle-income countries. However, most of the model-based analyses used effectiveness measures from meta-analyses that included some studies conducted in low and middle-income countries. Considering the ease of implementation of falls prevention exercise programmes, we would expect to find similar cost-effectiveness ratio in countries with lower income levels. This needs to be tested in future studies.

Strengths and limitations

This is the largest systematic review of economic evaluations and costing studies of fall prevention exercise programmes and the first to include both community and aged care settings. This was also the first review to attempt to explore the results according to participant and programme characteristics, to summarise

Table 3 Summary of results of the intervention costs of fall prevention exercise programs for older adults living in care facilities

Author/country (income)	Intervention name	Duration/frequency (range)	Supervision/supervised sessions, n, (who delivered)	Location (who with)	US$*/wk/person (median across studies, range)
Balance/functional					
Hewitt *et al*[10]†	Strength and balance exercise using specialised fitness equipment	52 wks 2 times/wk	26 (health professional) 84 (trained exercise leader)	Care facility (small group)	US$9
3D (tai chi)					
Wilson *et al*[56]‡	Yang-style tai chi	52 wks 2 times/wk	84 (tai chi instructor and care facility assistant)	Care facility (group, size NR)	US$3§
Multicomponent					
Buettner[57]¶	Walking and functional exercises	8 wks 3 times/wk (plus daily supervised walking)	56 (Health professional or physical activity leader)	Care facility (group, 3–5 participants)	Total cost/wk: US$295**

This table only includes studies where the intervention was powered for falls and had a significant impact on falls. Results for model-based, trial-based and costing studies are presented together.
One costing study[58] investigated an intervention that was not specifically designed to prevent falls and did not find an impact of the intervention on fall rate. The results of this study were omitted from this table but are presented in the other tables in the manuscript.
*In 2020 US$.
†Indicates trial-based economic evaluation.
‡Indicates model-based economic evaluation.
§We assumed that the total cost of the intervention was to deliver the intervention to 50 participants based on number of participants screened by the nurses.
¶Indicates costing study
**Number of participants engaging in the intervention not reported therefore it was not possible to calculate the cost per person per week.
NR, not reported; wk(s), week(s).

intervention costs, to conduct an in-depth appraisal of the risk of bias of the studies and to apply GRADE style rating to assess the certainty of the evidence. Our results are aligned with previous reviews that concluded that fall prevention programmes for older people living in the community are likely to offer good value for money,[13 29] although it was often unclear the methods and criteria used to judge an intervention as cost-effective in these previous reviews.

The following limitations should be considered when interpreting the results of this study. Although we used a comprehensive search strategy and searched specialised databases, we only searched electronic databases and performed hand search of peer-reviewed systematic reviews. It is possible that we may have missed economic evaluations of fall prevention exercise programmes that were not available in these sources. As anticipated, we were unable to pool the results by conducting a meta-analysis. There are often inherent challenges in comparing and combining the results of economic evaluations as they commonly have several differences, such as context and health service of the country, perspective, time horizon, cost items considered, methods for capturing costs and for calculating ICERs. We attempted to facilitate comparability between studies by reporting results in 2020 US$ and by displaying the results in figures. However, such approach has limitations as it does not consider the underlying heterogeneity between the studies. Additionally, uncertainty intervals were not displayed in the figures as these were rarely reported in the included studies. Therefore, caution is needed when interpreting the results of the figures and they should be analysed in combination with the detailed information provided for each study in the online supplemental tables and materials. There may be a risk of publication bias. There is presently no clear method to assess publication bias in reviews of economic evaluations as economic evaluation protocols are commonly not registered and trial-based economic evaluations should only be performed for interventions that are effective.

Several studies only reported results for natural outcomes (ie, fall-related outcomes). These results are useful when comparing interventions with the same outcome measure. However, natural outcomes do not allow us to examine whether the intervention represents value for money relative to other disparate healthcare programmes. A willingness-to-pay threshold for fall-related outcomes is currently not available in the literature, which makes the interpretation of results more challenging. Previous non-exercise fall prevention strategies, such as home safety programmes and multifactorial interventions have demonstrated similar results to the ones found in this review.[13 29]

Although we found that supervised programmes seem to offer better value for money than unsupervised programmes, these results should be interpreted with caution as social interactions in supervised programmes may contribute to the results of exercise interventions. However, as social interaction is a key component of supervised exercise it is not possible to disentangle the proportion of the effect observed that is due to the exercise programme itself or social interactions associated with the programme.

Recommendations for future research

Future economic evaluations of fall prevention exercise programmes should describe both alternatives in details, including the type of exercise, frequency, duration, as well as provide a detailed description of the control intervention as the content of the control intervention will influence the interpretation of results. Additionally, studies should report disaggregated values, that is, total costs per group, incremental costs and incremental outcomes, instead of only presenting ICERs, as the additional information would enhance the interpretation of findings. Studies should also express the uncertainty in the results by reporting uncertainty intervals and acceptability curves.

Future modelled economic evaluations should identify all relevant costs for both alternatives, clearly report the parameters used as well as their sources and report uncertainty intervals for the results. Additionally, extensive sensitivity and scenario analyses should be performed to test the robustness of the findings and to enhance interpretation of results. Farag *et al*'s study could be used as an example.[42] In this model-based analysis, different intervention costs, uptake levels and programme effectiveness were modelled in sensitivity analyses and, therefore, the results offer clear guidance to policy-makers considering implementing a fall prevention programme. In addition to reporting the results for the end of the time horizon, authors should also report intermediate results in a stepped manner so the impact of each of the steps of the model can be tested. Examples of intermediate results include results limited to trial-based data, results after application of utility weights, and extension of time horizon.

Future studies should consider using standardised methods for identifying and measuring costs and health benefits to enhance comparability of results. Additionally, they should present a detailed breakdown of the elements and costs involved in developing and implementing a fall prevention programme, such as training, staff and equipment to allow implementation. Unit costs should also be presented for each of these items. Actual intervention costs should be reported instead of costs based on recommendations for future applications, which could be explored in a scenario analysis.

Most of the trial-based economic evaluations included in this review only included fall-related healthcare utilisation. Future studies should consider including total healthcare utilisation as exercise may have additional consequences that are not captured by the fall-related healthcare utilisation measure. For instance, exercise may result in other general health benefits and therefore reduce other service utilisation that is not related to a fall. On the other hand, exercise may have unintended consequences and may increase the incidence of adverse events requiring medical attention that are not related to falls, such as musculoskeletal complaints. Therefore, capturing healthcare utilisation more broadly would offer a more comprehensive picture of the cost-effectiveness of the intervention.

Future primary studies investigating the effectiveness of fall prevention exercise programmes should consider including a trial-based economic evaluation, particularly those conducted in low-and-middle-income countries. Studies should also consider including a generic outcome measure such as QALY to enhance comparability with other interventions. We strongly recommended that future primary studies and reviews follow standard economic evaluation best-practice recommendations[17–19] and reporting guidelines, such as the Consolidated Health Economic Evaluation Reporting Standards statement.[61]

CONCLUSIONS

This review found a considerable number of economic evaluations (n=20, 11 of moderate certainty) investigating the value for money of fall prevention exercise programmes for older adults living in the community. The results of the economic evaluations varied, which probably reflects the heterogeneity between studies, with differences in the perspective taken, time horizon, healthcare systems between countries, which in turn influences

the cost consideration. However, for many of the studies, there is an indication of significant potential for cost-effectiveness of fall prevention exercise programmes. The intervention appeared to be more cost effective for 'older' old people (eg, 80+) and those with high fall risk. The evidence for older adults living in aged care facilities is limited but promising. The intervention costs varied, and no clear association was found between costs and type of exercise, location and level of supervision. The intervention costs summarised in this report should be interpreted considering exercise type, duration, level of supervision and number of participants. This information can be used for planning the implementation of future programmes or future models investigating the value for money of such programmes.

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Contributors MBP, CS, KH, AT, AS, FCB, JFW, ZM, NJF, AEB and SN developed the concept and protocol. MBP designed the search strategy, screened studies, extracted data, assessed the methodological quality of studies, conducted data synthesis and drafted and revised the paper. PC, JSO, SF and EM screened studies, extracted data, conducted data synthesis and developed the figures. NJF and ZM screened studies, assessed the methodological quality of studies and revised the paper. MBP, CS, KH, AT, AS, FCB, JFW, AEB and SN analysed and interpreted the data. All authors revised the draft paper and approved the final manuscript.

Funding This work was prepared for and funded by the Physical Activity Unit, Department of Health Promotion, Division of Universal Health Coverage and Healthier Populations, WHO.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

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