Journal of Orthopaedic Translation 24 (2020) 58–65

Contents lists available at ScienceDirect

Journal of Orthopaedic Translation

journal homepage: www.journals.elsevier.com/journal-of-orthopaedic-translation

REVIEW ARTICLE

The effectiveness of exercises on fall and fracture prevention amongst community elderlies: A systematic review and meta-analysis

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ARTICLE INFO

Keywords:
Exercise
Fall
Fracture
Prevention
Systematic review

SUMMARY

Objective: To analyze the effectiveness of exercise interventions on falls and fall-related fracture prevention among community-dwelling elderlies.

Methods: Literature search was conducted in Pubmed and Embase. Keywords used for literature search were "fracture" AND "fall" AND "exercise". Randomized controlled trials involving community-dwelling elderlies older than 60 years old with physical exercises as intervention were included. A systematic review and meta-analysis was performed. The primary outcomes were falls and fractures.

Results: Twelve studies were included and 4784 participants were involved with a mean age of 75.4. The most common exercise interventions were strength and balance exercises. The results of meta-analysis of 11 studies showed that exercise intervention had beneficial effect on fall prevention (RR = 0.71, 95% CI, 0.62–0.82; I^2 = 24%, $p < 0.0001$). The effect was better when exercise intervention applied to women participants (RR = 0.64, 95% CI, 0.49–0.83; I^2 = 28%, p = 0.00009) compared to men and women participants (RR = 0.75, 95% CI, 0.64–0.89; I^2 = 24%, p = 0.001). The results of meta-analysis of seven studies showed that physical exercise had significant effect on fracture prevention (RR = 0.54, 95% CI, 0.35–0.83; I^2 = 25%, p = 0.005). However, the effect was significant when exercise intervention applied to women participants only (RR = 0.37, 95% CI, 0.20–0.67; I^2 = 0%, p = 0.001) but not significant when exercise intervention applied to both genders (RR = 0.80, 95% CI, 0.58–1.09; I^2 = 0%, p = 0.15).

Conclusion: Exercise interventions, especially the combination of strength and balance training, were effective in preventing falls. Resistance exercises and jumping exercises were effective for fracture prevention among community-dwelling older population. The effectiveness of exercise interventions on fracture prevention have more significant effect on women. Further studies are needed to test the effectiveness of exercise interventions in men.

Translational potential: The use of effective exercises or biophysical interventions including vibration therapy can be incorporated into Fracture Liaison Services to prevent future fall and fracture.

Introduction

A fragility fracture is defined as a fracture caused by low-energy trauma and is a common cause of morbidity and mortality in the elderly. The event occurs in up to half of females and one-third of males who are older than 50 years of age [1]. These fractures cause pain and disability in the elderly resulting in a huge and growing financial burden to our healthcare society. The annual direct costs attributable to fracture treatment in the European Union equates to approximately 24 billion EUROs. Including indirect costs such as long-term care and facture prevention therapies, this figure rises to 37 billion EUROs per year [2]. Fragility fractures are most common in patients with osteoporosis [3,4]. To decrease these costs, strategies in preventing primary and secondary falls and fractures are essential.

The concept of imminent fracture risk has also been highlighted in recent studies, with a significant increase in fracture risk in the first 2

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https://doi.org/10.1016/j.jot.2020.05.007
Received 24 March 2020; Received in revised form 12 May 2020; Accepted 25 May 2020
Available online 1 June 2020
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years after an initial fracture [5,6]. This window of opportunity provides a golden period to prevent falls and fractures. With the development of Fracture Liaison Services, effective exercise interventions for rehabilitation and fall prevention should be incorporated [7,8]. Ultimately, these strategies will prevent further fractures and subsequent complications. Hip fractures are linked with 33% mortality in the first year and increased morbidity [9]. Loss of independence and deterioration of ambulatory capacity in activities of daily living (ADL) are common consequences after fragility fractures as it is strongly associated with the development of sarcopenia as well [10].

One of the key components of fracture prevention is taking the initiative to prevent falls in a targeted population [11]. There has been controversial evidence on exercise interventions in fracture prevention with previous meta-analysis studies being inconclusive due to the existence of publication bias [12]. However, more recent large-scale randomized controlled trials have provided new positive results [13,14], which may provide the latest evidence on the effectiveness of exercise interventions on fall and fracture prevention among elderlies. This is crucial for the incorporation of effective physiotherapy strategies in Fracture Liaison Services in the future. Therefore, the research question for this systematic review and meta-analysis was:

1. What is the effectiveness of exercise interventions on falls and fall-related fracture prevention among community-dwelling elderlies?

Materials and methods

Identification and selection of studies

A literature search was conducted in Pubmed and Embase. Last access to both databases was 3 June 2019. PRISMA guidelines was used. The keywords used for literature search were “fracture” AND “fall” AND “exercise”. The inclusion criteria were 1) randomized controlled trials investigating the effect of exercise interventions, 2) participants older than 60 years of age in the community, 3) outcome measures of fall reported 4) outcome measures of fracture reported. Exclusion criteria were 1) absence of control group, 2) participants received medication interventions e.g. steroids, etc. 3) fall or fracture outcomes not reported, 4) review papers and 5) articles not in English.

Selection of studies

2 reviewers conducted selection of studies independently. Duplicates were removed. Title and abstracts were screened and irrelevant papers were removed based on inclusion and exclusion criteria. Full text of potential relevant papers was retrieved and assessed for eligibility. Disagreements were settled by discussion and consensus.

Data extraction and synthesis

Information from eligible studies were extracted and presented: 1) study design and sample size, 2) means age and gender, 3) characteristics of the exercise in intervention group 4) frequency, duration, mode of delivery of exercise program 5) follow-up period, 6) activities of control group 7) fall and fracture outcomes.

Assessment of methodological quality

The recommendation of the Cochrane Collaboration was followed to assess risk of bias among the six domains: Random sequence generation, allocation concealment, methods of ascertaining falls or fracture, blinding of fall assessment, blinding of participants and personnel and incomplete outcome data [15]. For each domain, ratings were low risk, high risk or unclear based on whether the specific domain was performed.

Data analysis

The rate ratio of falls and the rate ratio of fractures of each study were the primary outcome of interest to show the effectiveness of exercise intervention compared to control group. The corresponding data were extracted from each study, and if the rate ratio was not reported, it was calculated from the total number of falls or fracture divided by the total length of time falls or fractures were monitored (person years) in the two comparison groups as recommended by the Cochrane handbook (chapter 9) [16]. The rate ratio (RR) and standard error (SE) were calculated by software Comprehensive meta-analysis (CMA, NJ, USA) with 95% confidence intervals. The effect of physical exercise performed on falls and fractures prevention was analyzed by Review Manager (RevMan 5.1; Cochrane Community, London, UK) and forest plots were assembled for the two categories by using a random effect model. Heterogeneity was tested with Cochran's Q statistic and I square test quantified the degree of heterogeneity, which I square value of 25%, 50% and 75% represented low, moderate and high degrees of heterogeneity respectively.

Results

Flow of studies through the review

The search strategy yielded 1103 publications, of which 251 were excluded due to duplicates from Pubmed and Embase. Another 804 trials were excluded as the papers were not related to the topic. A total of 48 full text articles were reviewed for eligibility, 4 studies were excluded as they were not randomized controlled trials, 20 did not report any outcomes on falls or fractures. 6 studies compared two exercise interventions without control groups. 5 studies were study protocols. 1 study had participants living in nursing homes. A total of 12 studies remained for further analysis. Please refer to Fig. 1 for PRISMA diagram.

Characteristics of included studies

A total of 4784 individuals participated in all studies, with sample size ranging from 44 to 1635 participants. The majority of the participants were women with a mean age of 75.4 years. 5 studies [13,17–20] involved women subjects only. 7 studies had an adherence rate more than 90%, whereas three studies had 85% adherence and two studies had approximately 70%. The studies were conducted in 7 countries, which were Finland [13,14,19], USA [21], Japan [20,22,23], Netherlands [24], Germany [17,18], Spain [25] and England [26] (see Table 1).

Exercise characteristics and delivery

Exercise interventions were provided to all participants in the intervention groups. These include resistance or strength exercise, balance training, jumping exercise, flexibility exercise, weight-bearing exercise, gait training, agility exercise, functional exercise and Tai Chi. All studies had balance exercise. 9 studies [13,14,17,18,20–22,25,26] combined balance and strengthening exercise. As for the remaining 3 studies, 1 study used balance exercise alone [19], 1 study used balance and jumping exercises [23] whilst 1 study combined balancing with weight bearing exercise [24]. 6 studies reported the mode of delivery with a combination of group and home exercises [18–21,25,26], 5 studies delivered via group form [13,14,17,22,24] and 1 study delivered exercise individually [23]. 5 studies [14,18,22,24,26] performed exercises 1–2 times per week, 3 studies [13,17,21] performed exercises 3–4 times per week. 2 studies [19,23] had daily exercise and 1 study performed group exercises every 2 weeks and home exercise 2–3 times per week [20]. Another study performed group exercise 5 sessions per week for the first three weeks and performed home exercises 4 times per week afterwards [25]. The total period of exercise intervention was up to 3 months in 2 studies [17,22], 6 months in 4 studies [19,20,23,26], 12 months in 2 studies [13,25], 18 months in 1 study [18], 24 months in 1 study [14]

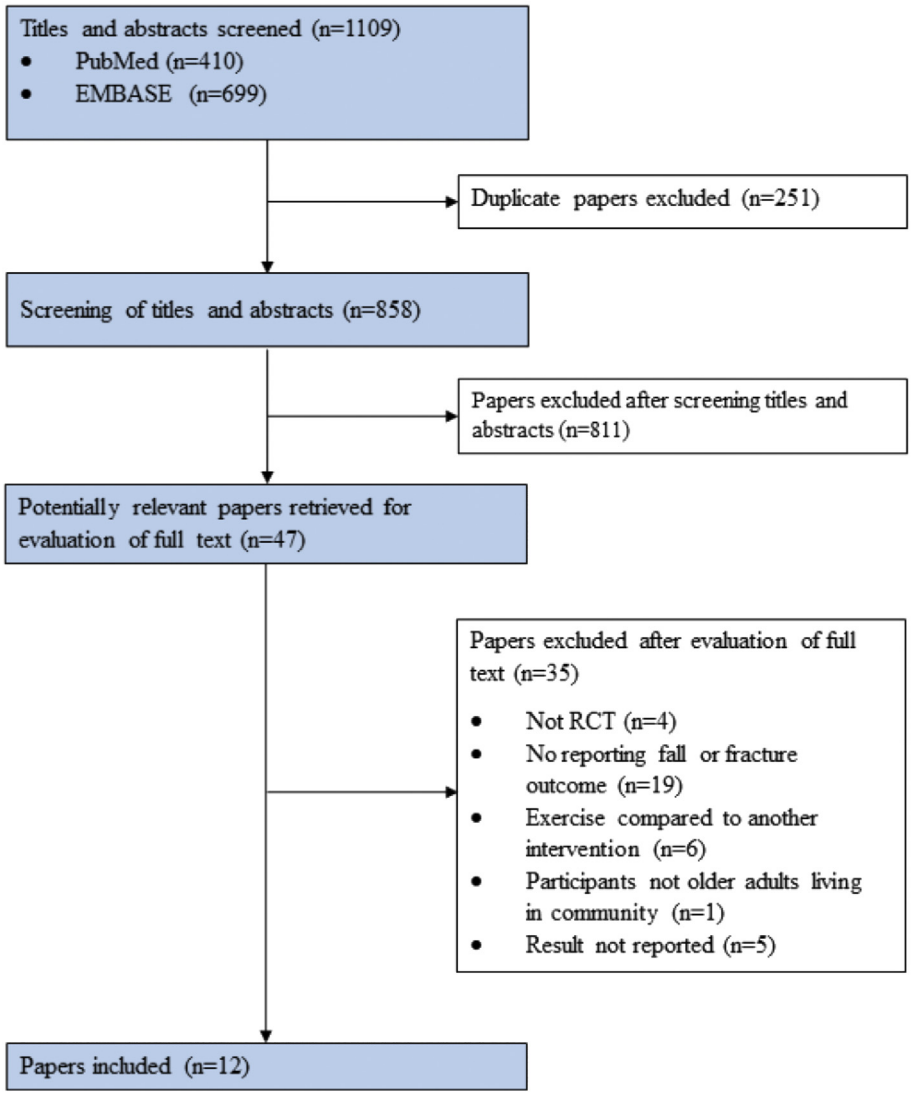

Fig. 1. Flow chart of literature search result.

and 1.4 months for 1 study [24]. For 1 study [21], the period of exercise was up to 24 months–42 months depending on the enrollment of participants.

Follow-up periods

4 studies had follow-up of 12 months [22,24–26], 2 studies had follow-up of 30 months [19,21] and 3 studies [14,18,23] had no follow up post-intervention and recorded fall or fracture incidence during the intervention period. The remaining studies had follow up at 3 months [17], 20 months [20] and 60 months [13].

Control group activities

In the control groups, there were no interventions in 6 studies [13,14,19,23,24,26]. Other studies used alternative activities including health education workshops [21], ball games and memory tasks [17], and pamphlet and advice on fall prevention [20,25]. 1 study gave a low-frequency, low-intensity task for 60 min per week for 10 weeks followed by 10 weeks of rest. The tasks included relaxation, games, dances, body sensitivity, deep breathing and general coordination [18]. The control group of another study [22] took a 60-min class once per month for 3 months focusing on nutrition, cognitive function and oral hygiene.

Risk of bias

The risk of bias of all studies were assessed. All studies performed randomized allocation and allocation concealment with low risk of bias. As for reporting bias, most studies had low risk of bias with participants using fall calendars [14,17,18,22,24,26], medical records [13,21] and by interview [20]. In 1 study, participants were asked whether a fall had occurred during follow-up [19] and another study only assessed the incidence of fall by asking participants every 3 months without record in a calendar, which has a risk of recall bias in elderlies [25]. One study did not report on the method of fall or fracture reporting [23], and risk of bias was unclear. For performance bias, 7 studies had both participants and outcome assessors blinded [13,14,18,19,22,25,26], 1 study had participants blinded only [21] and the remaining four studies [17,20,23,24] did not have any information regarding blinding. The majority of studies had low attrition bias and detection bias. There were minimal loss of subjects. The assessment of risk of bias in the included studies is in Table 2. 1 study did not report data related to number of fall and fracture rates and was therefore excluded from meta-analysis [21].

Table 1
Characteristics of included studies.

Author and year	No. of participants	Participant selection criteria	Mean age	Type of exercise	Mode of delivery	Exercise frequency	Intervention duration	Follow-up period (month)	Comparison group	Rate ratio of fall or fracture (person year)
Karinkanta, 2015	72	Lived independently at home, no osteoporosis	73.3	Resistance ex and balance-jumping ex	Group ex	3 times per week	12 months	5 years (60 months)	No intervention	Fall: 0.49 Fracture: 0.26
Korpelainen 2004	160	Elderly women with low BMD at radius and hip	72.8	Jumping and balance ex	Group ex and home ex	Daily, 1 h group ex+ 20 min home ex	6 months	30 months	No intervention	Fall: 0.788 Fracture:0.339
Gill, 2016	1635	70-79 yo short physical performance battery score <9, able to walk 400 m	78.9	Strength, flexibility and balance	Group and home ex	Group ex: 2 times per week Home ex: 3–4 times per week	24–42 months	2.6 years (31 months)	Educational program	Fracture:0.867
Sakamoto, 2012	865	Home dwelling elderly>75 years old	80.5	Single leg standing exercise	Supervised individual ex	1 min per set, 3 sets a day, daily exercise	6 months	No (6 months observation)	No intervention	Fall: 0.676 Fracture:0.404
Smulders, 2010	92	With osteoporosis and a fall history within 1 year	71	Balance, Walking ex, weight bearing ex, obstacle course, correction of gait	Group ex	11 sessions during 5.5 weeks	5.5 weeks	12 months	No intervention	Fall: 0.626 Fracture:0.319
Uusi-Rasi, 2015	205	Home-dwelling women, at least one fall history in previous year, no use of vit D and no contraindication to ex	74.2	Balance challenge, weight-bearing, strengthening, agility and functional exercise	Supervised group ex	2 times per week in first 12 months, once per week in another 12 months	24 months	No, Monthly reported fall in the observation time 24 months	No intervention	Fall: 0.98
Kemmler, 2010	227	65-year-old or older, living independently in community	69.1	Dynamic balance training, strength, stretching and weight bearing ex	Group ex and home ex	Once per week, 120 min for group ex, 40 min for home ex	18 months	No, observed in study time (18months)	Low- frequency and low intensity exercise, 60 min per week for 10 weeks and follow by rest for 10 weeks (18months duration)	Fall:0.54 Fracture:0.487
Hauer, 2001	57	Female geriatric patients admitted to acute care or inpatient reheb with history of injurious fall	82	Resistance training, progressive functional balance training	Group ex	3 times per week	3 months	3 months	Placebo activities, eg: flexibility ex, ball games and memory tasks	Fall:0.753
Suzuki, 2004	44	Community dwelling elderly women	78	Strengthening, walking, balance and tai chi	Group ex and home ex	Group ex: 1 h session every two weeks Home ex: 2–3 times per week, 30 min per day	6 months	20 months	Pamphlet and advice on fall prevention	Fall:0.25
Perula, 2012	404	community-living elderly	76.3	Walking, balance, strengthen and flexibility	Group ex and home ex	Group ex: 5 sessions/ weeks for 3 weeks, 90 min per session Home ex:	12 months	12 months	Received brief piece of advice about fall prevention and information leaflet	Fall:0.73

(*continued on next page*)

Table 1 (*continued*)

Author and year	No. of participants	Participant selection criteria	Mean age	Type of exercise	Mode of delivery	Exercise frequency	Intervention duration	Follow-up period (month)	Comparison group	Rate ratio of fall or fracture (person year)
						4 times per week, 30 min per sessions				
Kim, 2013	105	Age>70, at least a fall experience in previous year	77.8	Strength and balance	Group ex	Twice per week, each session for 60 min	3 months	12 months	Took a 60 min educational class once a month for 3 months, class focused on undernutrition, cognitive function and oral hygiene	Fall: 0.486 Fracture:0.51
Iliffe, 2014	845	Age >65 community living elderly	71	Strengthening and balance, endurance, flexibility, functional floor skills and tai chi	Group ex and home ex	Group ex: 60 min weekly ex class Home ex: twice per week, 30 min per sessions	24 weeks	12months	No intervention	Fall: 0.74

Table 2
Assessment of risk of bias in included studies.

Trial	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting falls/fracture	Other bias
Karinkanta, 2015	Low	Low	Low	Low	Low	Low	Low
Korpelainen, 2004	Low	Low	Low	Low	Low	High	Low
Gill, 2016	Low	Low	High	Low	Low	Low	Low
Sakamoto, 2012	Low	Low	Unclear	Unclear	Low	Unclear	Low
Smulders, 2010	Low	Low	Unclear	Low	Low	Low	Low
Uusi-Rasi, 2015	Low	Low	Low	Low	Low	Low	Low
Kemmler, 2010	Low	Low	Low	Low	Low	Low	Low
Hauer, 2001	Low	Low	Unclear	Low	High	Low	Low
Suzuki, 2004	Low	Low	Unclear	Low	Low	Low	Low
Perula. 2012	Low	Low	Low	low	Low	High	Low
Kim, 2013	Low	Low	Low	Low	Low	Low	Low
Iliffe, 2014	Low	Low	Low	Low	High	Low	Low

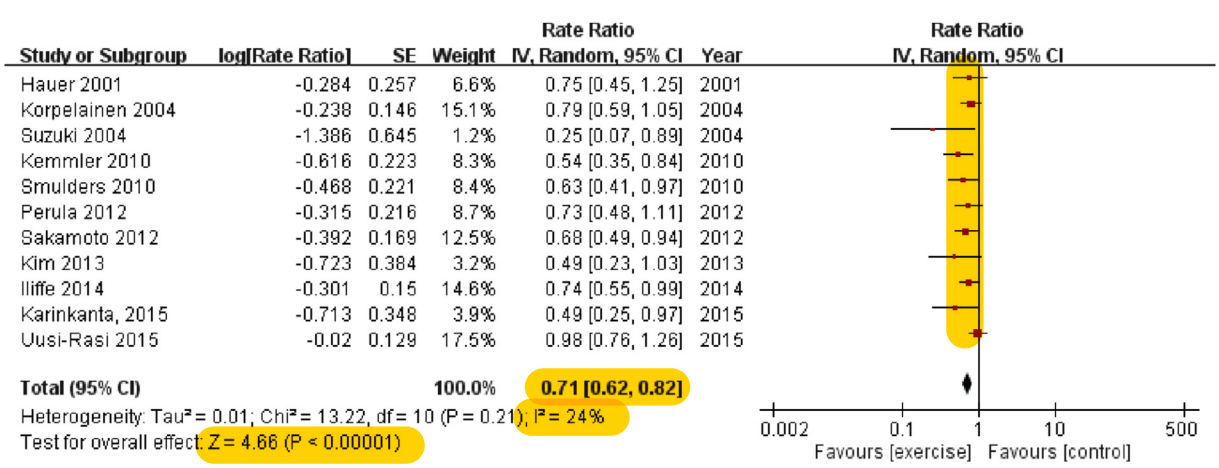

Fig. 2. Overall effect of exercise intervention on fall prevention.

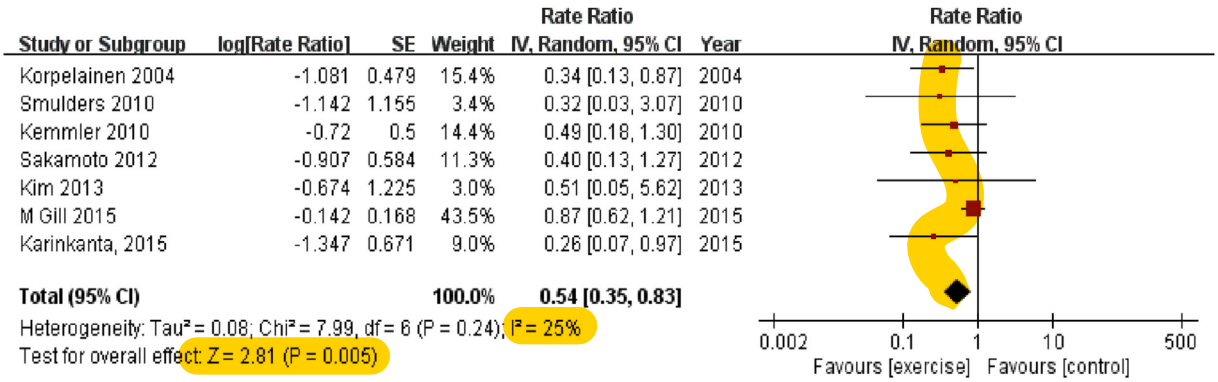

Fig. 3. Overall effect of exercise intervention on fracture prevention.

Meta-analysis

The results of the meta-analysis of all 11 studies [13,14,17–20,22–26] showed that exercise intervention had significant beneficial effect on fall prevention (RR = 0.71, 95% CI, 0.62–0.82; I^2 = 24%, p < 0.0001) (Fig. 2). The effect was even better when exercise intervention was performed on women participants [13,17–20] (RR = 0.64, 95% CI, 0.49–0.83; I^2 = 28%, p = 0.00009) (Fig. 4) compared to both genders [14,22–26] (RR = 0.75, 95% CI, 0.64–0.89; I^2 = 24%, p = 0.001) (Fig. 5). The results of meta-analysis of the 7 studies [13,18,19,21–24] showed that physical exercise also had a significant effect on fracture prevention (RR = 0.54, 95% CI, 0.35–0.83; I^2 = 25%, p = 0.005) (Fig. 3). The effect was significant when exercise intervention was applied to women participants only [14,18,19] (RR = 0.37, 95% CI, 0.20–0.67; I^2 = 0%, p = 0.001) (Fig. 6) but not significant when exercise intervention was performed on both genders [21–24] (RR = 0.80, 95% CI, 0.58–1.09; I^2 = 0%, p = 0.15) (Fig. 7).

Discussion

This meta-analysis showed that exercise intervention produced positive effect on fall prevention and reduction of fractures in elderlies. The exercise regimen used by participants were mostly a combination of resistance or strengthening training with balance exercises [13,14,17,18,20–22,25,26], with the incidence of fall significantly reduced. Muscle strength and balance are key elements for preventing falls from muscle weakness and sarcopenia [27]. There is strong evidence supporting strengthening or resistance exercises to enhance quadriceps which acts as a static and dynamic balancer for older people [28]. Lower limb muscle strength is crucial for mobility and physical function [29]. Therefore, these exercises are important and should be involved in multi-component exercises intervention, and can play an important role in fall prevention programs [30]. Almost all hip and wrist fractures and approximately 30% of vertebral fractures are caused by falls [31]. Balance exercises are an alternative type of training which aims to prevent falls. There are different ways to deliver balance exercise among studies but the principles are similar. Exercises that decrease the base of support, shift the center of mass side-to-side, stepping up and down with minimal hand support, single leg stance, tandem walking, obstacle courses, and Tai Chi are commonly performed [13,14,17–26].

Our results concur with a previous review performed by Gillespie et al., in 2012 [32], which reported that the prevention of falls amongst community dwelling older adults included strengthening exercise and balance training. However, further to the analysis, our current study also investigated the effect of exercise interventions on fracture prevention. The occurrence of a fracture significantly affects clinical outcomes and healthcare costs. Ensuring the optimal exercise intervention for fracture prevention allows the potential incorporation into our Fracture Liaison Services [33]. It is important to have effective prevention of secondary fractures as the mortality is significantly higher.

Bone fragility is generally considered a major contributing factor of fracture occurrence [34]. However, deterioration of lower limb strength, loss of balancing ability and fall episodes may be the biggest risk factors causing fractures in the elderly [11]. An effective fall prevention exercise program is as important as treating bone health amongst elderlies [35]. In fact, exercises have been shown to bring positive effects in patients with osteoporosis [35], osteonecrosis [36], etc. This meta-analysis provides evidence that effective exercise programs are effective in fall prevention and benefit in reducing fractures. The meta-analysis by Kemmler et al. [12] showed some beneficial effect of exercises on fractures prevention among elderly but was not significant due to publication bias. Heterogeneity of trial results were also a major problem. Falls were not analyzed in the study and the meta-analysis comprised of both randomized controlled trials and non-randomized controlled trials. With the recent publications of further randomized controlled trials in this topic, we were able to conduct an updated review. The result of the current meta-analysis is focused on both fall and fall-related fractures with only randomized controlled trials to decrease risks of bias.

Our subgroup analysis showed exercise intervention was effective in preventing falls when applied to either women or both genders. But the effect of fracture prevention was significant in women only and not significant when both genders were involved. The result showed that the effectiveness of exercise on fracture prevention may be different between men and women. The study by Woo et al. [37] compared the effect of Tai Chi and resistance exercise on bone mineral density (BMD) changes between older men and women. The result showed no positive effects on BMD changes in men but significant BMD changes at the hip in women subjects. Our previous animal studies have shown that estrogen may play an important role. Ovariectomized rats, which are estrogen deficient, has higher response to mechanical stimulation as compared to sham rats [38]. However, further research is needed in order to understand the exact mechanisms. For these reasons, more effective strategies may be required to prevent falls and fractures in male patients. Currently there is lack of studies focusing on the effectiveness of exercises in men. Recent studies have been investigating the use of vibration therapy as an intervention to prevent falls in fragility fracture patients [39]. Vibration therapy is a biophysical intervention which is non-invasive and has been proven to have positive effects in quadricep muscle strength, balancing and gait speed.

Based on our results, the most effective exercises in preventing falls are strengthening and balance exercises, which is highlighted in most studies. Suzuki et al. showed balancing exercises with Tai Chi and strengthening exercises for a 6 month period had the lowest rate ratio in the prevention of falls [20]. As for the prevention of fractures, resistance exercises and balance-jumping exercises are most effective. Karinkanta et al. showed that these exercises for 12 months had the lowest rate ratio for fractures [14]. The strengths of this study are that it is composed of randomized controlled trials only, therefore reducing bias. The analysis is

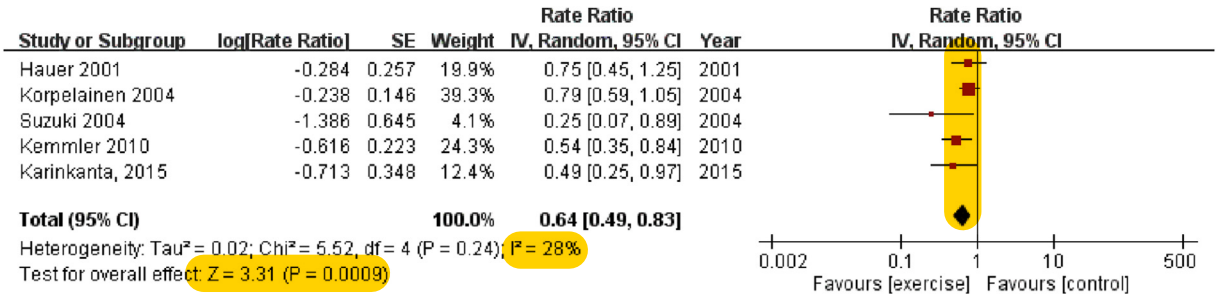

Fig. 4. Overall effect of exercise intervention on fall prevention in women only.

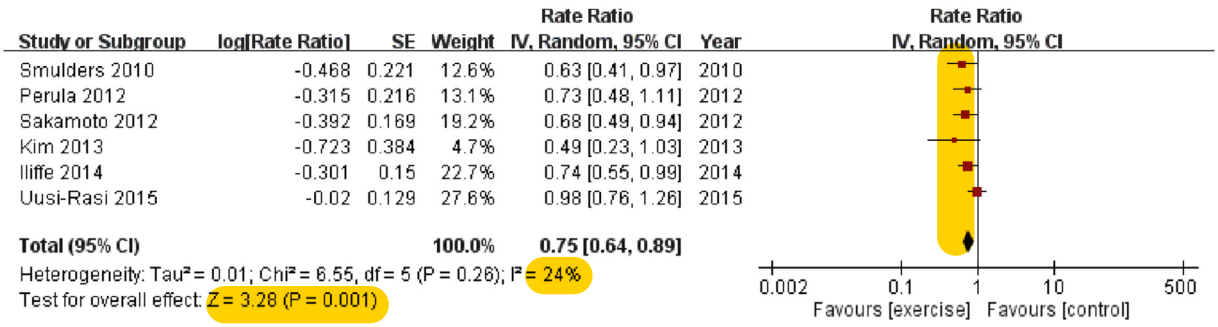

Fig. 5. Overall effect of exercise intervention on fall prevention in both gender.

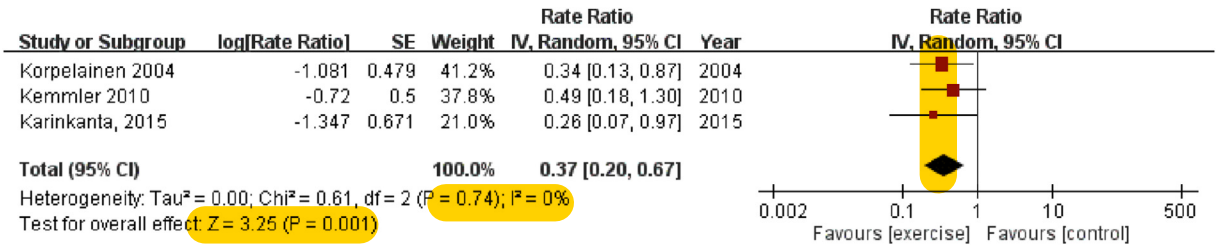

Fig. 6. Overall effect of exercise intervention on fracture prevention in women only.

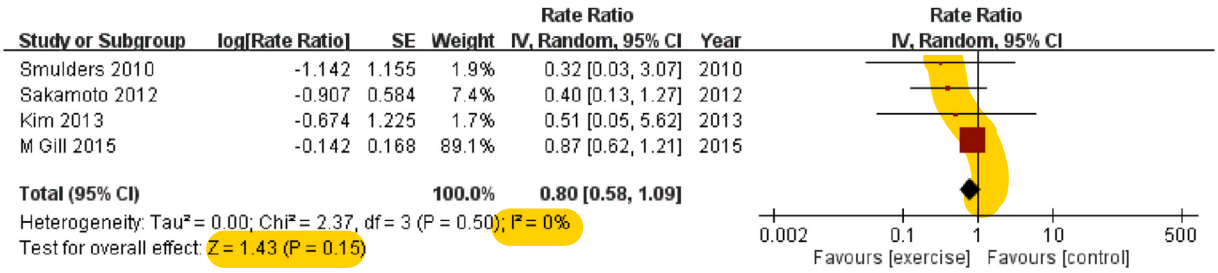

Fig. 7. Overall effect of exercise intervention on fracture prevention in both gender.

also more updated with the recent publishment of several studies. There are some limitations in this study. For the outcome measures, some studies did not apply fall calendars to record fall events which is a well-established method in collecting fall data. This may cause inaccuracies in the fall incidence rate [40]. There was also heterogeneity in follow-up periods between studies.

Conclusion

In conclusion, our results show that physical exercise can prevent falls and fall related fractures in elderlies. There are two important components for fall prevention which are balance and strength training and should be involved in fall prevention programs. Future incorporation of resistance exercises and balance-jump exercises into Fracture Liaison Services should be performed. Currently, the exact mechanisms as to why the effectiveness of exercise interventions on fracture prevention have more significant effect on women is still unclear. Further studies are also needed to test the effectiveness of exercise interventions in men in terms of fall and fracture prevention.

Conflict of Interest

The authors have no conflicts of interest to disclose in relation to this article.

Acknowledgement

This study was supported by the Hong Kong Research Grants Council Early Career Scheme (Reference no. 24108519).

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