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REVIEW

Prevention of falls in the elderly—a review

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Abstract The proportion of elderly in the society increases and fall frequency increases with advancing age. Many falls result in fractures and also soft tissue injuries, longstanding pain, functional impairment, reduced quality of life, increased mortality, and excess in healthcare costs. Due to the magnitude of these negative effects, a variety of single- and multicomponent fall-preventive intervention programs has been initiated.This review identifies programs that, in randomized controlled trials (RCTs), have been shown with fall-reductive effects.The most effective strategies in community-dwelling elderly include regular physical training with program that includes several different training modalities. Modification of the overall or patient-specific risk factor profile in home hazard modification program has been proven to decrease fall risk in community-living elderly. The elderly in the community benefit also from wearing antislip shoe devices when walking in icy conditions, from adjustment of psychotropic medication, and from structured modification of multipharmacy. If vitamin D levels in blood are low, supplementation is beneficial as is the first eye cataract surgery and pacemaker implantation in patients with cardioinhibitory carotid sinus hypersensitivity. In addition to modification of specific risk factors, generalized and individualized multifactorial preventive programs, all including some sort of physical training, have been found to decrease the fall risk. In summary, there is now strong evidence in the literature that structured fall-preventive programs in the elderly, especially in high-risk groups, are beneficial in reducing both the number of fallers and the number of falls in community.

Keywords Elderly · Epidemiology · Falls · Fractures · Prevention · Randomized controlled trials

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Introduction—epidemiology of falls

The total number of fractures has risen during the recent 50 years [1, 2] resulting in an estimated worldwide prevalence of fragility fractures in adults above the age of 50 years in 9 million, of which 1.6 million were hip, 1.7 million forearm, and 1.4 million clinically diagnosed vertebral fractures [3]. This increase is estimated to continue due to both changes in demographics and fracture patterns, thereby making fragility fractures an even greater challenge in the future [4] (Fig. 1). Two of the most important risk factors for fractures are fall and bone fragility. Approximately one third of community dwellers aged 65 years or more and 50–60 % of residents of nursing and old people's homes fall annually where women as a group sustain more falls and have a higher proportion of fallers than do men [5]. In year2000 in the USA, there was an estimated 10,300 fatal and 2.6 million nonfatal but medically treated fall-related injuries in individuals above the age of 65 years [6]. Falls are not only a risk factor for fractures but also for development of traumatic cerebral or visceral hemorragia, traumatic pain syndromes, functional limitations, dislocations, soft tissue injuries, excess healthcare costs, and increased mortality [7]. For example, 23 % of injury-related deaths in patients over 65 years of age and 34 % in those over 85 years of age occur after a fall [8]. Furthermore, 10–15 % of the falls in patients living in the community and 15–20 % of falls in

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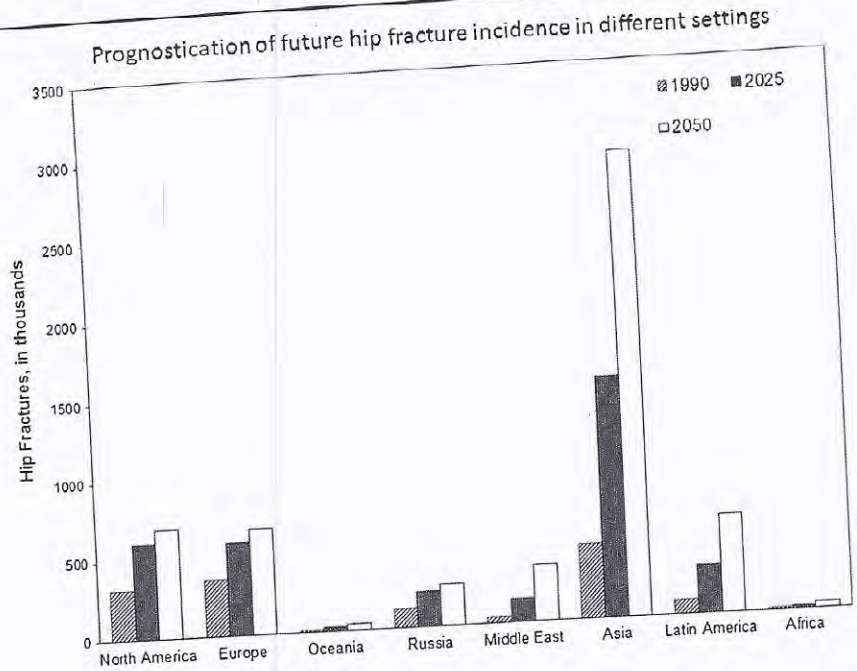

Fig. 1 When the available incidence rates for hip fracture from various parts of the world has been applied to projected populations in 1990, 2025, and 2050 in order to estimate the numbers of hip fractures which might occur in each of the major continental region [4]

institutionalized patients result in significant injuries [9]. Fractures occur in 3–12 % of falls in the elderly, more common in women than men [10], and hip fractures occur in less than 1 % of all falls [11]. The annual incidence of hip fractures in those with a tendency to fall is 7 % but as much as 14 % in frequent fallers and is as a result, in the USA, the second highest injury-related cost to society [12]. These data have shifted some of the focus from prevention of osteoporosis to prevention of falls when trying to reduce the number of fragility fractures and pointed out the need of intensified fall prevention within the healthcare system. This review therefore aims to identify fall-preventive strategies proven effective in the aspect of fall reduction or reduction in the number of fallers in community-living elderly and in elderly living in hospital settings and nursing homes in randomized controlled trials (RCT).

Association between falls and fractures

A frail or osteoporotic patient will have to sustain only a minor trauma, most often in the form of a fall, to suffer a fracture but without any fall or other trauma virtually no fracture will occur. Risk factors for fragility fractures can be divided into two types, those related to trauma such as tendency to fall and those related to bone strength such as bone mineral density (BMD), skeletal architecture, and/or bone size [13]. But several risk factors, such as immobility and aging, operate through both skeletal and extraskeletal routes [7, 14]. For example, age-related increase in fracture risk is only partly explained by increased bone loss and older patients are at greater risk of fracture than younger patients, independently of their level of bone mass. As individuals with multiple risk factors are at especially high risk for fracture [13], it is clinically important to determine also other specific risk factors. Among risk factors for fracture, fall is usually regarded as the most central and most risk factors are also similar for falls and fractures [10, 11]. But falls also gradually become a more potent risk factor for fractures with advancing age [15].

Causality of fall

Intrinsic risk factors for falls include old age, female gender, low body mass, medical comorbidities, musculoskeletal diseases, cognitive impairment, gait and balance disorders, sensory impairments, postural hypotension, history of previous falls, use of certain medications such as benzodiazepines, sedative–hypnotic drugs, antidepressants, antihypertensive drugs, antiarrhythmia drugs, diuretics, and antiseizure medications [10, 11, 16–19]. In contrast, environmental hazards such as rugs, slippery or uneven floors, poor lighting, electrical cords, chairs and armchairs without handrails, slippery surfaces, and unsuitable footwear are often classified as extrinsic risk factors [10, 11, 16–19].

Noticeably, many risk factors, including advanced age, are related to both falls and reduced bone strength [7, 14] and are therefore especially important for fracture risk. It is even possible to influence both BMD and the fall risk by prevention programs [18, 20–22]. In addition to intrinsic risk factors, 50–80 % of patients treated in accident or emergency departments for consequences of a fall, report environmental home hazards as one of the causes of the fall

[23]. These risk factors vary and interact individually [24] and the risk of a fall rises rapidly as the number of risk factors increases. For example, women with a high calcaneal BMD but with more than four clinical risk factors had a higher risk of sustaining a fall-related hip fracture than women with low BMD but few other risk fractures: The highest risk to sustain a hip fracture was found among women with the lowest BMD and more than four other risk factors [13].

Modification of risk factors for fall

Risk factors for falls and fractures can also be divided into modifiable and nonmodifiable factors, where both can be used as markers for future fall risk but only modifiable risk factors can be addressed by preventive strategies to reduce the future fall risk. This accounts for most of the extrinsic risk factors such as rugs and assistance devices, but also for some intrinsic risk factors such as impaired neuromuscular function [25]. Given the complexity of the overall fall risk, any intervention program should cover and treat as many intrinsic risk factors as possible to maximize the effect. Ideal fall and fracture preventions strategies should further identify high-risk groups and include changes such as adequate calcium intake, supporting exercise, improving functional ability, treating health disorders, and avoiding multipharmacy as well as addressing modifiable intrinsic factors [20, 21].

A history of falling is one of the strongest independent risk factors for additional falls. It is therefore especially important to evaluate every elderly person attending health care with a fall. This has been successfully utilized in the Prevention of Falls in the Elderly Trial in which structured intervention decreased the future fall risk by 70 % in patients attending an emergency department with a fall-related injury [26]. Interventions included (1) individual management, addressing patient specific factors, (2) reduction of environmental hazards, (3) appropriate reduction of medication, (4) individual education in behavior strategies, (5) training in getting up after a fall, and finally (6) exercise programs improving strength, balance, and aerobic capacity.

Inclusion criteria for this review of fall preventive interventions

As there currently is strong evidence supporting the effectiveness of several fall-preventive strategies, this review summarizes the specific prevention programs effective in RCTs. We identified potentially interesting studies through a structured search in PubMed from all years by using the terms: "accidental falls", "physical therapy", "equipment", "supplies", "self-help devices", "protective devices", "environmental intervention", "home modification", "exercise", "exercise therapy", "physical education", and "training". From the identified studies, we included only those evaluating the effects of interventions designed to reduce falls in older people, evaluated in RCTs, in individuals aged 60 years or more or if described as elderly, seniors, or older. The participants should be living in the community at home or in places of residence that do not provide residential health-related care. Trials that included younger participants, for example, recruited on the basis of a medical condition such as a stroke or Parkinson's disease was included if the mean age −1 standard deviation was more than 60 years. Some references found evaluated interventions in nursing care facilities or hospitals, but these data are presented separately. In studies with participants living in different settings, participants were included if data were provided for subgroups based on setting. The intervention was compared with "usual care" or "placebo". Studies that evaluated two types of fall-prevention interventions were also included. Finally, we went through the included studies and excluded those without the end-point variables rate or number of falls or number of participants sustaining at least one fall during follow up (fallers). Apart from these studies, we also included published structured reviews and Cochrane reviews within the field that summarized the outcome in published RCT [17–19, 22, 27–31]. We choose to present studies reported in these Cochrane reviews in the figures while additional reports could be referred to in the text. In the figures, we do not show all RCT included in the Cochrane review from 2012 (n=159), instead we conducted selective inclusion of the central studies. Finally, we also reviewed the reference lists of each to identify papers fulfilling the aforementioned criteria to add further relevant RCTs.

The meta-analyses calculations referred to in this paper are in detail reported in cited Cochrane reviews [17–19]. In summary, in the meta-analyses, data from different RCTs with comparable interventions and participant characteristics were pooled by use of generic inverse variance method. Calculated pooled rate ratios for the total number of falls or risk ratios for being a faller with 95 % confidence intervals were estimated through the fixed-effect model. Where there was substantial statistical heterogeneity, data were pooled using a random effect model [19].

Even though this review is a structured approach, all reviews are subjected to the risk of bias. Different authors can rate publications differently. There could have been further biases in recall of falls, a common finding in old people. Falls were registered heterogeneously in the included studies, in some by the use of falls diaries, in others relying on participants recall over longer intervals during the study or at its conclusion. Furthermore, also the dropout frequency differed between studies, a fact that could influence the inferences. In the meta-analyses, pooled data were used; but all interventions were not done in the same way

and participants differed in age, morbidity level, and gender. Also, this could influence the results. In such a broad search that was done in this review, it is possible that the search strategy could have identified duplicate publications on the same cohort reported in different ways in different studies. The majority of the included studies were however individually randomized, but some were cluster randomized from community physician practice, retirement villages, or senior centers or cluster randomized by household where more than one person in the household was recruited. Inclusion of cohorts from all different parts of the world could also confound our inferences as different ethnical groups may respond differently to intervention. The sampling were also different between studies, some were population based while others included volunteers and since the sampling years were different, both period and cohort effects could exert an influence

Prevention of falls by physical activity

RCTs have shown that physical training programs, and then especially with compliant participants [32–34], reduce the risk of falling in community-dwelling elderly [17–20, 22, 32, 35–59] (Fig. 2). Among the exercise programs, multicomponent exercise programs, that is training programs with different exercise modalities, is the most effective fall-prevention strategy in the general community-living elderly population [60–63] (Fig. 2). This seems to be the only intervention strategy that reduces both the number of individuals that falls and the fall rate in fallers [18, 19]. All other effective interventions in the general population reduce only one of these two variables [18, 19]. Therefore, exercise has been described as the most cost-effective strategy for preventing falls and fractures in community-dwelling older adults [60–63].

In multicomponent exercise programs, the two most important components seem to be balance training and muscle strength training, followed by flexibility and endurance training [18]. The most effective training in the elderly is conducted at a high amount and with a high frequency [20, 54]. Supervised group exercise, when at least including two different training components, decreased the rate of falls by 22 % (relative risk [RR] 0.78, 95 % CI 0.71–0.86) and the risk of falling by 17 % (RR 0.83, 95 % CI 0.72–0.97) in population-based included community-living adults above the age of 60 years (Fig. 2). This positive effect was found also in elderly with high risk to fall (Fig. 2). Other training program including only gait and balance or functional training also significantly reduce the rate of falls by 27 % (RR 0.73, 95 % CI 0.54–0.98) but not the risk of falling (RR 0.77, 95 % CI 0.58–1.03; Fig. 2). Four RCTs compared different types of exercise and how the training was delivered but could not find any differences between different types of training modalities or how the training was delivered [18, 19].

Individualized exercise programs for home training utilizing more than one exercise category have, in intervention studies of community-dwelling elderly, been found to reduce the fall rate by 34 % (RR 0.66, 95 % CI 0.53–0.82) and the risk of falling by 23 % (RR 0.77, 95 % CI 0.61–0.97) [18] (Fig. 2). Among specific type of exercises examined, Tai Chi training seems to be the most effective single-training modality [54, 64] (Fig. 2). One often-cited RCT evaluating fall-protective training was published by the Frailty and Injuries: Cooperative Studies of Intervention Techniques group where in a subgroup analyses, Wolf et al. reported that Tai Chi reduced the number of falls by almost 50 % [64]. This strong effect is probably attributable to the fact that Tai Chi contains a combination of both strength and balance training. In a meta-analysis of pooled data [18], this view was supported when in community-living elderly reporting that Tai Chi training reduced the number of falls by 37 % (RR 0.63, 95 % CI 0.52–0.78) and the risk of falling by 35 % (RR 0.65, 95 % CI 0.51–0.82; Fig. 2). Another recent published RCT showed that home-based balance and strength training in elderly community-living individuals aged 70 years or older who had two or more falls or one injurious fall in the past 12 months, was followed by a 31 % reduced number of falls (RR 0.69, 95 % CI 0.48–0.99) [65]. The authors concluded that functional-based exercise should be a focus for interventions to protect older, high-risk individuals from falling and that this type of functional training provides an alternative to traditional exercise for fall prevention. A music-based multitask exercise program in community-dwelling elderly older than 65 years who were at increased risk of falling was also effective and the program resulted in 54 % fewer falls in the exercise group (RR 0.46; 95%CI 0.27–0.79) [66].

Gillespie et al. [18] and Sherrington et al. [22] also inferred in their reviews that walking should not be the only method with the aim to improve performance since there is no fall-preventive effect by only this type of physical activity in community-living elderly, probably since falls in elderly usually occur during walking [67]. This view is supported by two RCTs that investigated effects of general physical activity in the form of walking groups [68, 69]. Both studies reported that walking alone did not reduce the number of falls or the risk of falling. The same conclusion was drawn when only advocating specific-designed muscle-strengthening exercises [22], even if other researchers have inferred that strength training as one component of multicomponent exercise strategies could be of relevance for fall reduction [18, 36, 70].

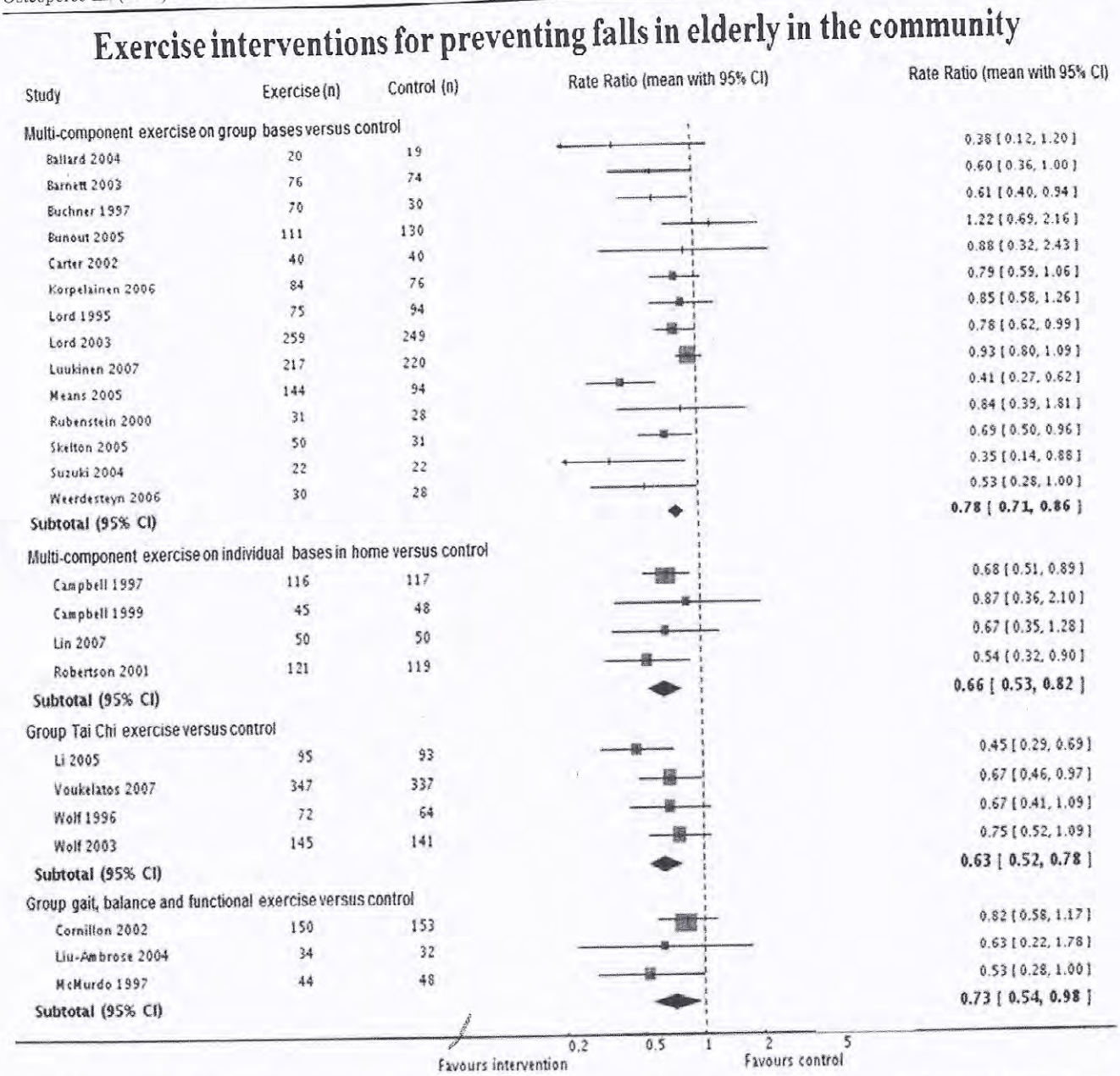

Fig. 2 Comparison of number of falls in community-living elderly exposed to interventions with different types of exercise versus controls reported in several RCTs [18, 19]

Unfortunately, the effect of physical training on fall risk seems to be lower in all type of institutionalized individuals [17, 71–77] (Fig. 3). In these individuals, supervised training reduced the fall risk by 56 % (RR 0.44, 95 % CI 0.20–0.97) in hospitalized patients above age 65 years who stayed in subacute care hospitals [17] but not in patients who stayed in general nursing care facilities (Fig. 3). However, training by mechanical apparatuses in the later patient category reduced the fall rate by 55 % (RR 0.45, 95 % CI 0.24–0.85). That is, specific types of training in difficult-to-target groups as nursing home residents or other types of hospitalized individuals can be effective for fall prevention (Fig. 3).

Prevention of falls by vitamin D supplement

In one Cochrane review [18], 13 RCTs evaluated the fall-preventive efficacy of supplementation with vitamin D analogs, either alone or with calcium as cosupplementation. The overall analysis of vitamin D versus control found no significant difference in fall rate when provided to unselected community-dwelling elderly (RR 0.95, 95 % CI 0.80–1.14) [18, 19, 78–84] (Fig. 4). Adverse effects such as hypercalcemia, renal disease, and/or gastrointestinal effects were similar in the intervention groups and the control groups in the three trials that reported adverse effects [18,

Exercise interventions for preventing falls in elderly in nursing care homes and hospitals

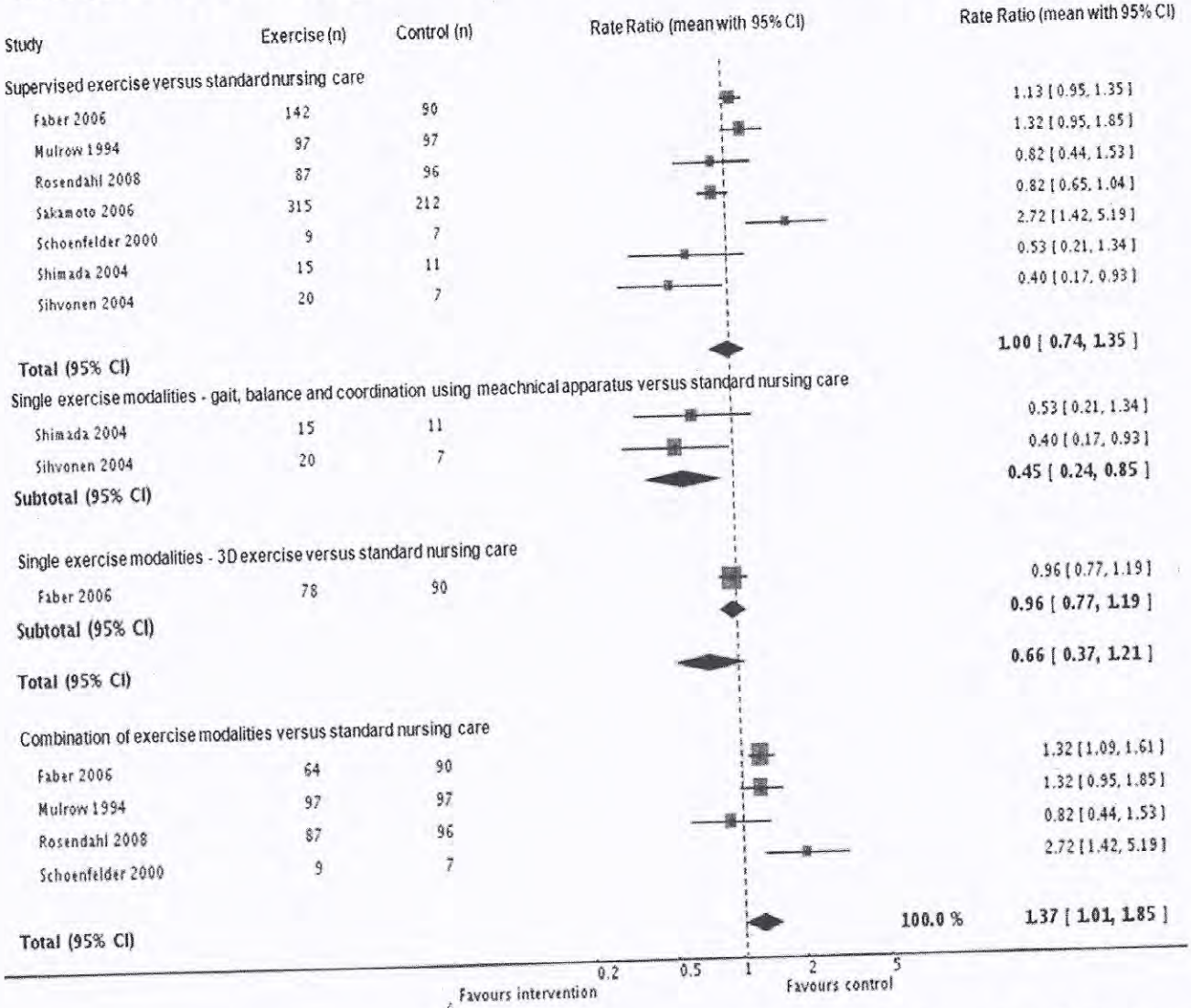

Fig. 3 Comparison of number of falls in elderly living in nursing home or hospitals exposed to intervention with different types of exercise versus controls reported in several RCTs [17]

19]. Slightly more positive conclusions could be drawn when the supplement was given to institutionalized elderly, where the total number of falls was reduced by 28 % (RR 0.72, 95 % CI 0.55–0.95) while the number of fallers were unaffected (RR 0.98, 95 % CI 0.89–1.09) [17] (Fig. 4). In pooled data analysis, the fall rate was significantly reduced by 43 % with supplement in participants with low vitamin D levels at baseline (RR 0.57, 95 % CI 0.37–0.89) as was the number of fallers by 35 % (RR 0.65, 95 % CI 0.46–0.91) [80, 81] (Fig. 4) while no such effects was found in participants with normal vitamin D levels at baseline [18, 19]. The relationship is however complex making it difficult to evaluate the true fall-preventive effect of vitamin D supplement as the type of vitamin drug prescribed seems also to influence the fall preventive effect. For example, alfacalcidol was not associated with reduced fall frequency (RR 1.08, 95 % CI 0.75–1.57) [84] whereas calcitriol reduced the fall frequency by 36 % (RR 0.64, 95 % CI 0.49–0.82) [83] (Fig. 4).

Prevention of falls by drug target interventions

Gradual withdrawal of psychotropic medication was in one RCT found to significantly reduce the rate of falls in community-dwelling elderly by 66 % (RR 0.34, 95 % CI 0.16–0.73) but not significantly reduce the risk of falling (RR 0.61, 95 % CI 0.32–1.17) [48] (Fig. 5). One study

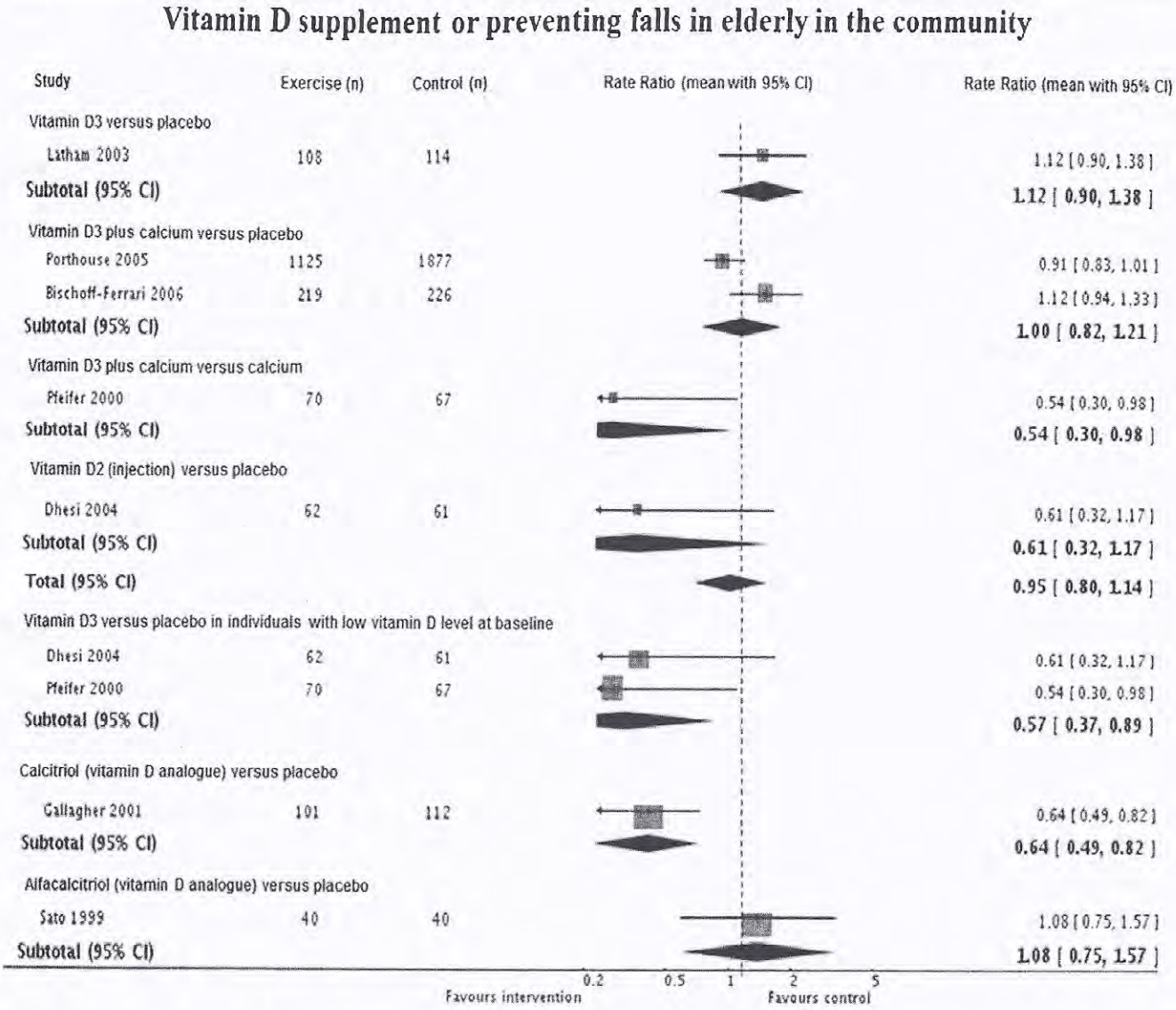

Fig. 4 Comparison of number of falls in community-living elderly exposed to vitamin D supplement with or without calcium versus controls reported in a variety of RCT [18, 19]

included a major educational component for family physicians, caring for community-dwelling elderly that included fall-preventive education, feedback on prescribing practices, and financial rewards combined with self-assessment of medication use by the patients. This structured approach was followed by a subsequent medication review and optimization and resulted in a 39 % reduced fall risk (RR 0.61, 95 % CI 0.41–0.91) [85] (Fig. 5). Furthermore, a prescribing modification program by a pharmacist in nursing care facilities or hospitals was found to reduce the fall frequency by 38 % (RR 0.62 95 % CI 0.53–0.72) [48]. We conclude that structured reduction of different type of multipharmacy can reduce the number of falls.

Prevention of falls by surgical interventions

Surgical treatment in specific risk groups with specific diagnoses can be an option to reduce the number of falls. Cardiac pacemaker insertion in individuals with cardioinhibitory carotid sinus hypersensitivity was in one published RCT found to reduce the rate of falls by 58 % (RR 0.42, 95 % CI 0.23–0.75; Fig. 5), but not in the number of people that fell [86]. First eye cataract surgery was in another RCT found to reduce the rate of falls by 34 % (RR 0.66, 95 % CI 0.45–0.95; Fig. 5), but not the numbers of fallers (RR 0.95, 95 % CI 0.68–1.33) [87]. Interestingly, in participants receiving cataract surgery for the second eye, there was no additional fall reductive effect [88] (Fig. 5).

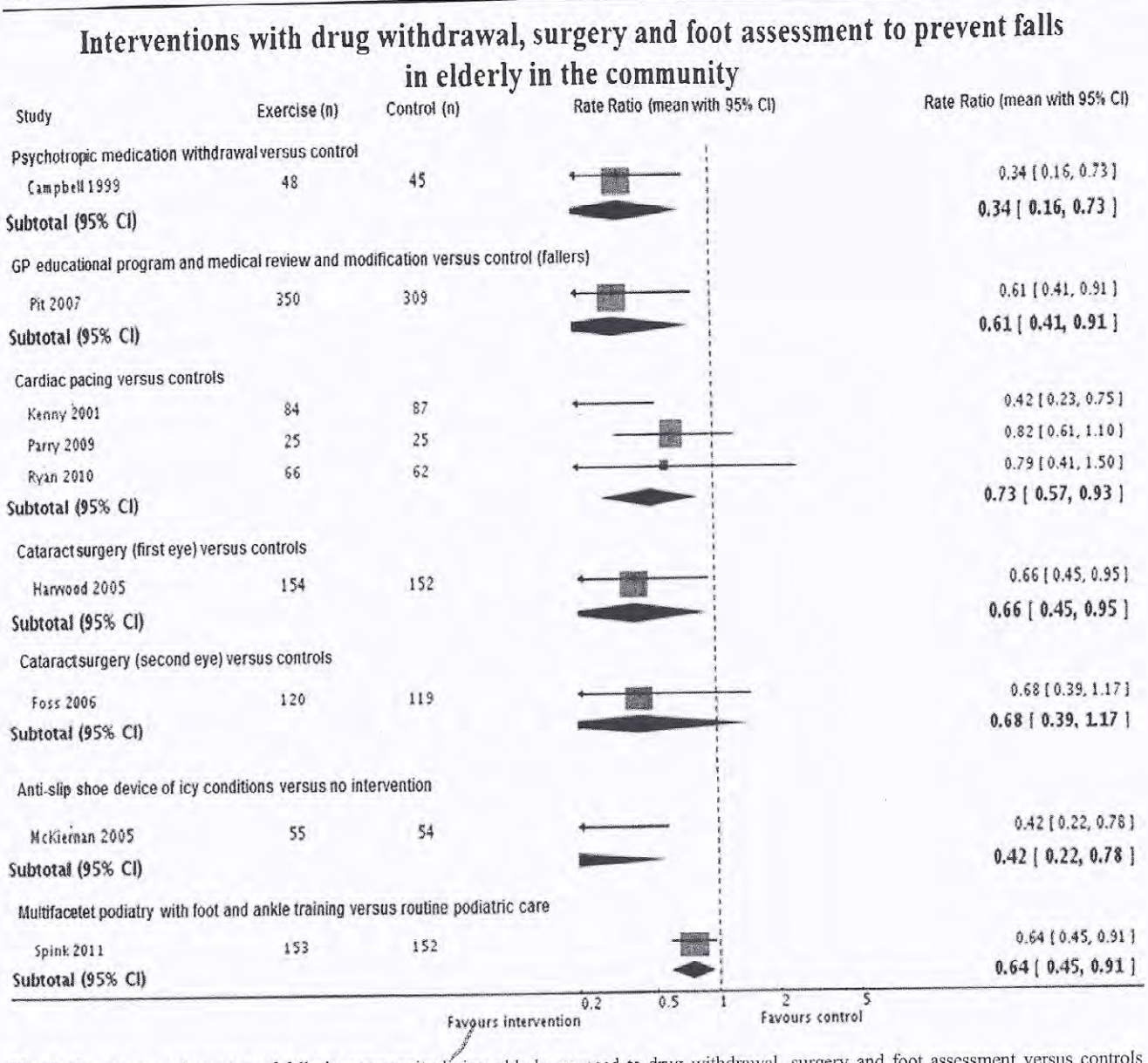

Fig. 5 Comparison of number of falls in community-living elderly exposed to drug withdrawal, surgery and foot assessment versus controls reported in a variety of RCT [18, 19]

Prevention of falls by home hazard modification

Most falls resulting in a fragility fractures occur indoors, even more evident in individuals above age 80 years [89]. In this group, it is therefore extra important to focus on home safety through home hazard modification [29, 51, 90–95]. Modification of home hazards in the general elderly population reduce the number of falls (RR 0.81, 95 % CI 0.68–0.97; Fig. 6) and the number of fallers (RR 0.88, 95 % CI 0.80–0.96) [19, 51, 90, 91, 93, 96]. In addition, the effect was most obvious when the program was conducted by occupational therapists [19, 90, 93, 97, 98] (Fig. 6). In a fall-prevention program, individuals above age 75 years with visual impairment who were recommended to remove or change loose floor mats, paint the edges of steps, reduce glare, install grab bars and stair rails, remove clutter, and improve lighting where needed had a fall reduction of 41 % (RR 0.59, 95 % CI 0.42–0.83; Fig. 6) and a reduction in the number of fallers by 24 % (RR 0.76, 95 % CI 0.62–0.95) [18, 93]. A further subgroup analysis based on fall risk found that home safety programs significantly reduced the rate of falling in high-risk individuals (such as those with a history of a fall or multiple risk factors), with a fall reduction of 44 % (RR 0.56, 95 % CI 0.42–0.76; Fig. 6) but not in the lower-risk subgroup (RR 0.92, 95 % CI 0.80–1.06; Fig. 3). Also, the number of fallers was significantly reduced in the higher-risk subgroup (RR 0.78, 95 % CI 0.64–0.95) but not in the lower-risk subgroup (RR 0.90, 95 % CI 0.80–1.00) [18, 25]. Thus,

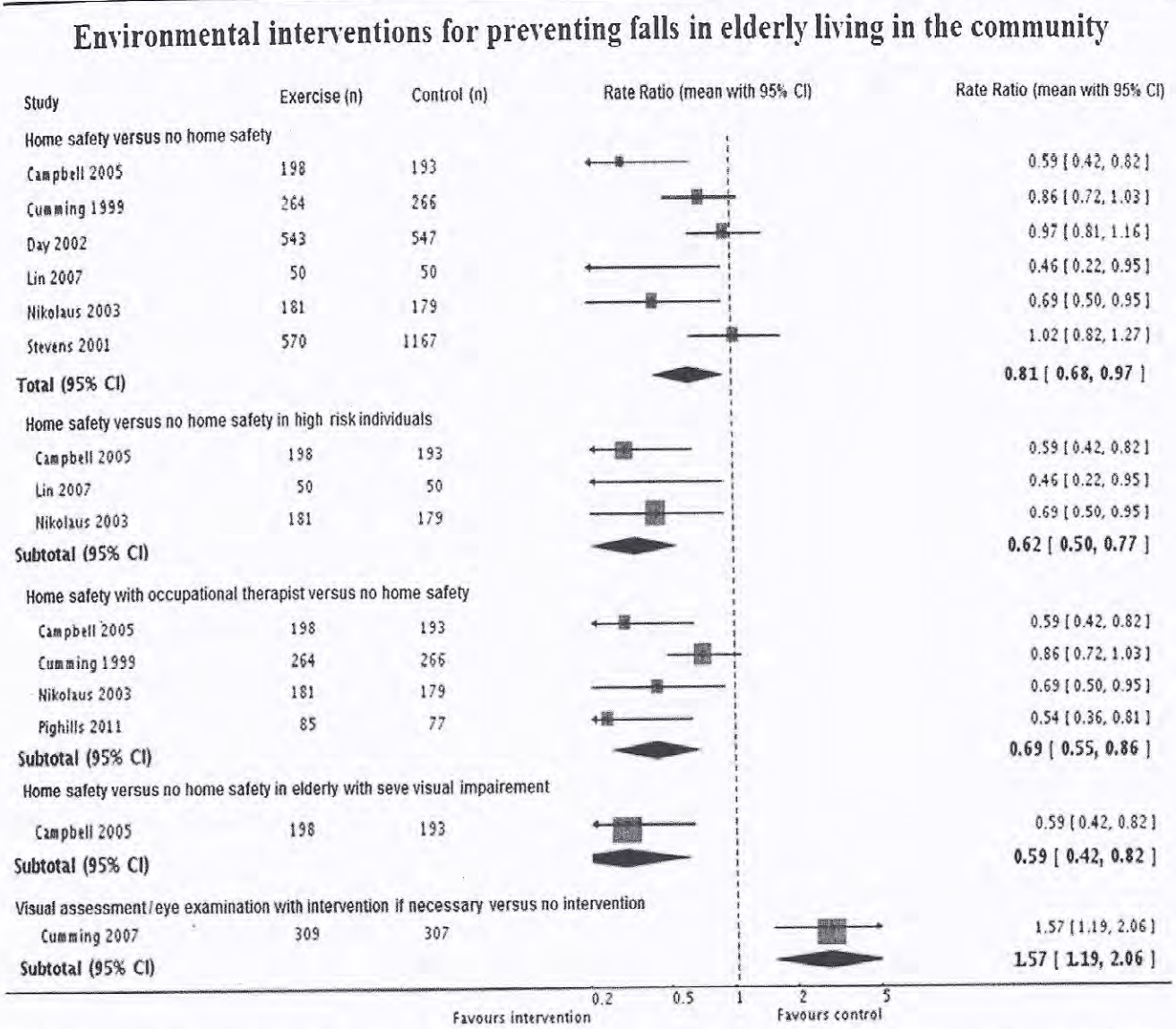

Fig. 6 Comparison of number of falls in community-living elderly exposed to intervention with home hazard assessment followed by risk factor reduction versus controls reported in several RCTs [18, 19]

home hazard assessment and modification is effective also in the general elderly population not only in risk cohorts [19].

Prevention of falls by specific footwear

Footwear in elderly individuals may also influence the risk of falling [99, 100]. Shoes are commonly changed during the day depending on the location or activity making evaluation difficult. However, the oldest individuals mainly fall inside their home [89] and falls in elderly individuals are in general more associated to an intrinsic risk of falling such as severe medical problems and poor functional ability, whereas younger and healthier individuals who move outdoors and are thus more prone to sustain slips and falls related to environmental hazards [89, 101] possibly addressable by optimal footwear. Outdoor fall accidents are hence attributed not only to footwear properties but also to other environmental factors such as temperature, snowfall, and lighting [102]. One RCT has shown that the use of antislip shoe devices during icy conditions reduced the rate of falls by 58 % (RR 0.42, 95 % CI 0.22–0.78) and injurious falls that did not require hospitalization by 87 % (RR 0.13, 95 % CI 0.03–0.66) in fall-prone older individuals [18, 94] (Fig. 5). Another RCT that evaluated the effect of multifaceted podiatry including foot and ankle exercise found that this intervention reduced the fall risk by 36 % (RR 0.64, 95 % CI 0.45–0.91) compared to standard podiatry in patients with disabling foot pain but not the risk of falling [103] (Fig. 5). Antislip shoe devices should therefore be recommended to ambulatory elderly who walk outdoors under

icy conditions and multifaceted podiatry to patients with specific foot disability.

Prevention of falls by general multifaceted interventions

In relation to advancing age, fall-related problems steeply increases such as physiological changes, diseases, drug intake, visual impairment, development of sarcopenia. Many of these factors decrease the ability to regulate movements and to compensate for a slips or disturbed balance during everyday activities [104]. Falling should be regarded as failure of a complex system of factors, each necessitating specific attention and intervention [104, 105]. Hypothetically, multifaceted intervention would therefore be the ideal intervention strategy [17, 18] where each individual is evaluated in a structured fashion for risk factors for falls and if being found as a high-risk individual, referred to an individually designed prevention program. This strategy is in contrast to general intervention programs with fixed combination of components of intervention that is delivered to all participants independent on individual risk factors. Multifaceted general intervention programs are probably easier to introduce to the individual and result in high compliance. Similar programs regularly include exercise, care planning, medical and/or diagnostic approaches, changes in physical environment, education programs, calcium and vitamin D supplementation, medication review, and removal of physical restraints (for example, bedside rails) [17–19, 30, 93, 106–109] (Fig. 7). With these standard generalized programs, Clemson et al. [107] reported 31 % fall reduction when using a combination of exercise, education, and a home safety intervention (RR 0.69, 95 % CI 0.50–0.96); Swaneburg et al. [109] reported 81 % reduction with exercise plus nutritional supplementation in vitamin D and calcium-replete women (RR 0.19, 95 % CI 0.05–0.68); Day et al. [96] reported 24 % reduction with an exercise component and home safety assessment (RR 0.76, 95 % CI 0.60–0.97), 27 % with exercise plus vision assessment (RR 0.73, 95 % CI 0.59–0.91), and 23 % with exercise plus vision and home safety assessment (RR 0.67, 95 % CI 0.51–0.88). Finally, Assantachai et al. [110] reported 23 % reduction in the risk of falling when using an educational intervention combined with free access to a geriatric clinic assessment (RR 0.77, 95 % CI 0.63–0.94; Fig. 7).

Prevention of falls by individualized multifactorial interventions

In individualized multifactorial interventions, the participants are exposed to different combinations of interventions based on their individual assessments [18, 19, 23, 26, 111–122] (Fig. 8). Gillespie et al. reported that individualized multifactorial interventions reduce the rate of falls in community-dwelling older adults by 25 % (RR 0.75, 95 % CI 0.65–0.86) but not the number of individuals who fall [18] (Fig. 8). For individuals in hospital settings, similar interventions reduced the rate of falls by 31 % (RR 0.69, 95 % CI 0.49–0.96) and the risk of falling by 27 % (RR 0.73, 95 % CI 0.56–0.96) while no effect was found in elderly in nursing home facilities. A subanalysis in nursing home caretakers however showed that the rate of falling decreased by 40 % (RR 0.60, 95 % CI 0.51–0.72) and the risk of falling by 15 % (RR 0.85, 95 % CI 0.77–0.95) when using multidisciplinary teams and physical training [17]. It should also be noted that all multiple interventions trials with beneficial effects included an exercise component [17, 18] (Fig. 8) and that multifactorial risk assessment in conjunction with comprehensive management of identified risk factors usually are recommended to focus on high-risk populations. In the recently updated American Geriatric Society clinical practice guidelines, this especially accounts for older adults who have sustained two falls or more in the recent year, have gait or balance problems, or have presented with an acute fall.

Intervention strategies without effects

No published RCTs have shown that assistive devices such as canes and walkers, as a single intervention, reduce the number of fallers or the number of falls. However, these devices have been used for centuries with good clinical results and without any adverse side effects or high costs. Absence of evidence of effect is however not evidence of absence of effect; assistive devices have also been included in multifaceted interventions that in RCTs has been proven effective for fall reduction [17, 18, 30]. Few would therefore recommend clinicians to stop prescribing canes or other walking aids.

Nutritional supplementation has been proposed as a possible fall-preventive intervention. However, in RCTs with this intervention, the risk of falling has not been reduced in frail older women receiving oral nutritional supplementation such as fluid or nutrition therapy [123]. Another RCT evaluated if cognitive behavioral intervention was effective, a study that concluded this type of intervention to be of no benefit for fall reduction [124]. Two RCTs have evaluated if an intervention program aiming to increase the patient's knowledge of fall prevention reduces falls [95, 125] and found no evidence of reduction in rate of falls or the risk of falling by this intervention.

Interventions with harmful effects

Interventions may not only be ineffective, they can even be harmful. For example, one RCT found that vision assessment and eye examination resulting in new spectacles or ophthalmologic treatment was associated with a 57 %

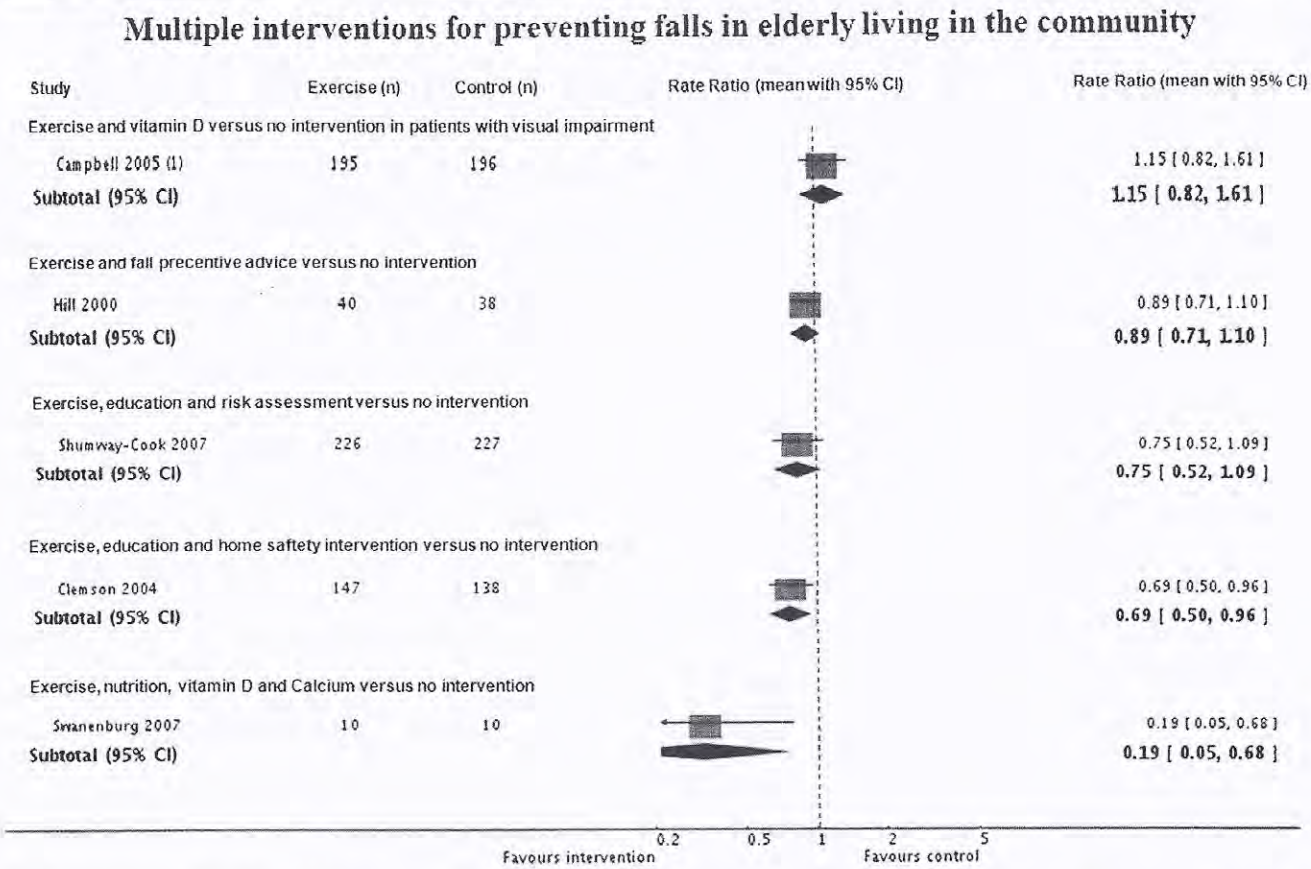

Fig. 7 Comparison of number of falls in community-living elderly exposed to generalized multifaceted interventions versus controls reported in a several RCTs [18, 19]

increased fall risk (RR 1.57, 95 % CI 1.19–2.06) and a 54 % increased risk of being a faller (RR 1.54, 95 % CI 1.24–1.91) [92] (Fig. 6). Physical activity may in community-living individuals be one of the most efficient fall-reductive prevention strategies [18] but training is not equally efficient in all groups of individuals. Generalized training programs with different combination of exercises not tailored to each specific individual in hospitalized individuals was for example in one study found to increase the rate of falls by 172 % (RR 2.72, 95 % CI 1.42–5.19) [74] and when looking at pooled data from several studies by 37 % (RR 1.37, 95 % CI 1.01–1.85) [17] (Fig. 3). Each specific fall prevention intervention program must therefore be evaluated in the intended cohort beforehand and the results cannot instantly be transferred to other cohorts.

Cost–benefit

There are few RCTs with cost–benefit estimations on the fall-preventive interventions as outcome (n=8) [18]. In these, there was only weak evidence for the cost-effectiveness of prevention strategies for fall reduction during the trial periods and probably also during the rest of the lifespan of the participants. The reports also infer that to obtain maximum value for money, the prevention strategies, ought to be targeted at particular subgroups of older people at especially high risk to fall to gain the highest cost–beneficial effect [18].

Conclusions

Two strong determinants of fracture in elderly is fall and bone fragility. The prevention of falls is therefore one of the most important tasks for the healthcare system not only in order to reduce the number of fractures but also other trauma-related injuries. Several physical training therapies have been shown to be efficient as presented in this report. The most effective approach to reduce both the risk and rate of falls in elderly community-dwelling individuals is multi-component exercise programs targeting strength, balance, flexibility, or endurance. Programs that contain two or more of these components reduce the risk of falling as well as the rate of falls. Exercise in supervised groups, participating in Tai Chi, and carrying out patient-specific exercise programs at home are all effective. In institutionalized individuals, exercise training alone does not appear to be effective to

Multifactorial interventions for preventing falls in elderly living in the community

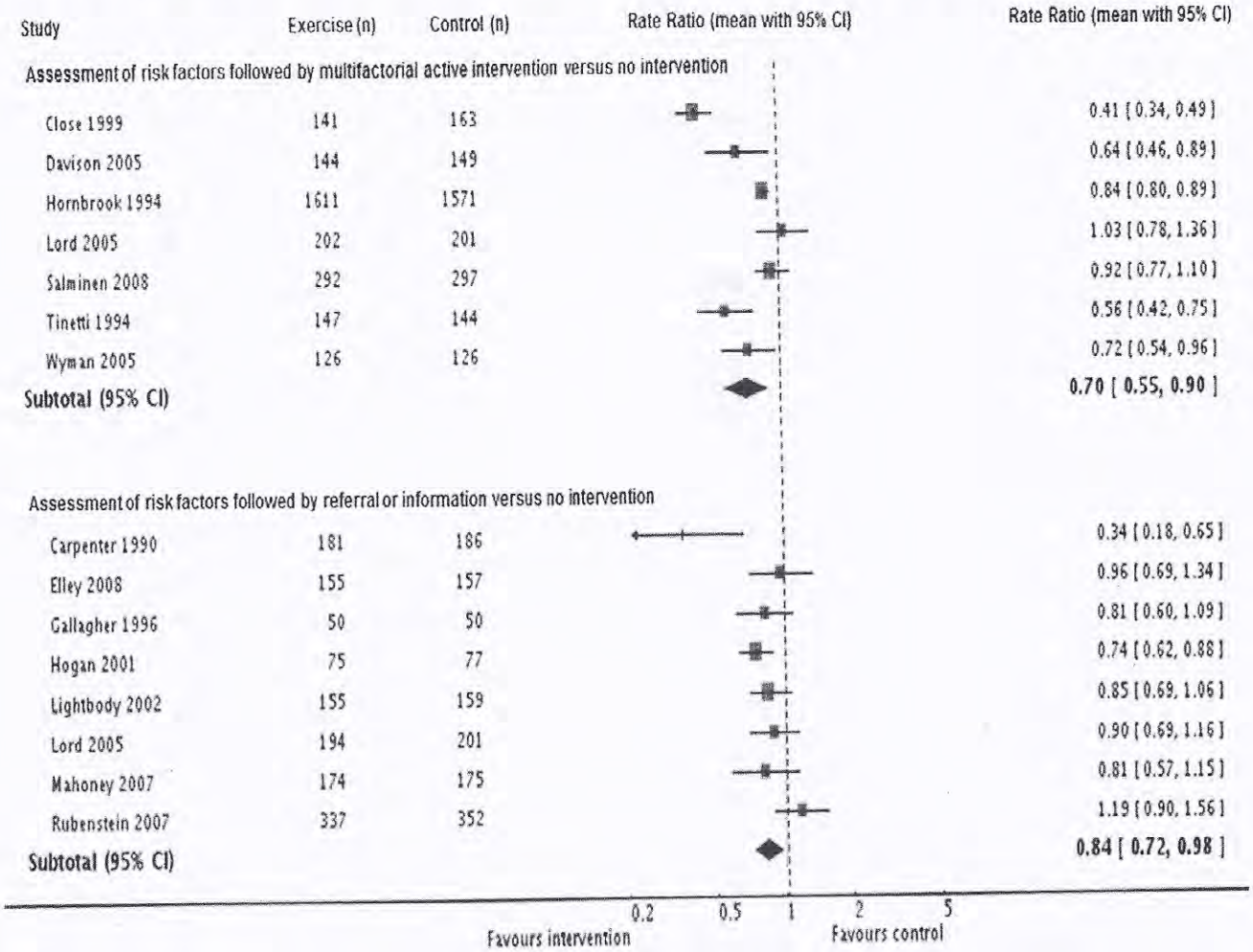

Fig. 8 Comparison of number of falls in community-living elderly with individualized multifactorial interventions versus controls reported in several RCT [18, 19]

prevent falls and fractures, except for in persons in a subacute care hospital setting. Home hazard assessment with modification of risk factors has been proven efficient for community-living elderly with most obvious beneficial effect in high-risk groups. Antislip shoe devices are effective for fall reduction in elderly walking outdoors in icy conditions. Multifaceted podiatry to patients with specific foot disability reduces the fall risk in these patients. Multifaceted interventions and multifactorial programs, which include several individually tailored preventive components, have in some studies been shown to be effective, but not in others. These programs should always include an exercise training component possibly the most cost-effective single component for the prevention of falls. Overall, current evidence infers that they do reduce rate of falls in older people living in the community and seems to be even more efficient in those at the highest risk of falls. Ideally, these programs should be tailored to the individual. These interventional programs are complex, and their effectiveness may be dependent on factors yet to be determined. In general though, multifaceted interventions with some element of physical therapy as well as other important preventive measures seem to be of value. Vitamin D supplements probably do not reduce falls, except in people with a low level of vitamin D. Some medications increase the risk of falling. Ensuring that medications are reviewed and optimally are effective in reducing falls, a gradual withdrawal of some drug types for improving sleep, reducing anxiety, and treating depression has been shown to reduce the number of falls. First eye cataract surgery can reduce falls in the visual impaired as can insertion of a pacemaker in patients with and a history of syncope and/or falls associated with carotid sinus hypersensitivity, a condition which may result in changes in heart rate and blood pressure. Some interventions may however be

harmful and increase falls. Nontailored exercise in hospitalized individuals may increase the fall frequency and in the visually impaired, evidence point to an increased risk of falling when adjusting to new spectacles or major changes in prescription.

The implications of the findings in cited studies ought to have a great impact on everyday clinical practice and future research directions. To reduce the number of falls, the evidence-based preventive strategies must be implemented in all levels of the healthcare system. Focus should be directed to the actual widespread implementation of interventions into clinical practice as well as to improve patient adherence. New RCTs ought to be initiated to evaluate new preventive strategies and strategies presently in use but without support in RCTs such as the use of canes as single prophylaxis. Future studies should also evaluate subcohorts with high fall risk not evaluated in this review.

Conflicts of interest None

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