The Impact and Prevention of Fall-Related Injuries among Older Adults

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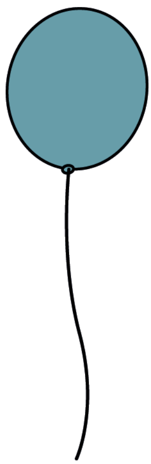

CHAPTER 1

General introduction

Falls among older adults: trends and characteristics

Falls among older adults are a major public health problem worldwide. The increasing incidence of falls is related to an ageing population. Globally, the number of older adults increased from 390 million to more than 650 million in the past two decades [1]. This number is expected to increase to nearly 1.5 billion in 2050, which is accompanied by a large rise in life expectancy [2]. In the Netherlands, a similar trend was observed in the past twenty years, as the older adult population increased by 155% [3]. During that time, life expectancy at birth rose from 78 to 82 years. The aging population has resulted in a rise in age-related chronic diseases. In 2017, more than a quarter of the older adults had diabetes or cardiovascular disease, and almost half of the older adults had cancer [4]. The demographic changes are also related to an increasing number of falls among older adults. Old age is often accompanied by a sedentary lifestyle, leading to a deterioration of balance, mobility, and strength. Together with vision changes and side effects of medication, the chances of falling increase considerably. In the Netherlands, fall-related injury and mortality represents an important and growing problem among older adults (Figure 1). In the past decades, the number of fall-related hospital visits and fatalities increased drastically [5, 6]. Currently, every five minutes an older adult visits an Emergency Department (ED) following a fall [7]. It is estimated that the number of fall-related hospital visits and fatalities will keep increasing in the next ten years [7]. The impact of falls among older adults are documented in other Western societies, as well. In the past decades, increased fall-related ED visits, hospital admissions, and fatalities have been observed in the United States, Canada, Australia, and in several European countries [8-15]. Falls among older adults have a major impact on healthcare costs [16]. This does not only relate to fall-related ED visits and hospital admissions, but also to minor injuries treated at a general practitioner. In the United States, an estimated $10 billion is spent yearly on treating fall-related injuries among older adults [17]. In the Netherlands, almost €900 million was spent on these injuries in 2017, which is equivalent to an average direct medical cost of €8.200 per patient [7]. Apart from the impact of falls on healthcare costs, falls have a large impact on the lives of older adults, as well. Falls can result in functional decline, loss of autonomy, and in a reduced quality of life [18, 19]. As the majority of fall-related injuries treated at an ED in the Netherlands are classified as severe [17], these effects could continue for an extended period of time.

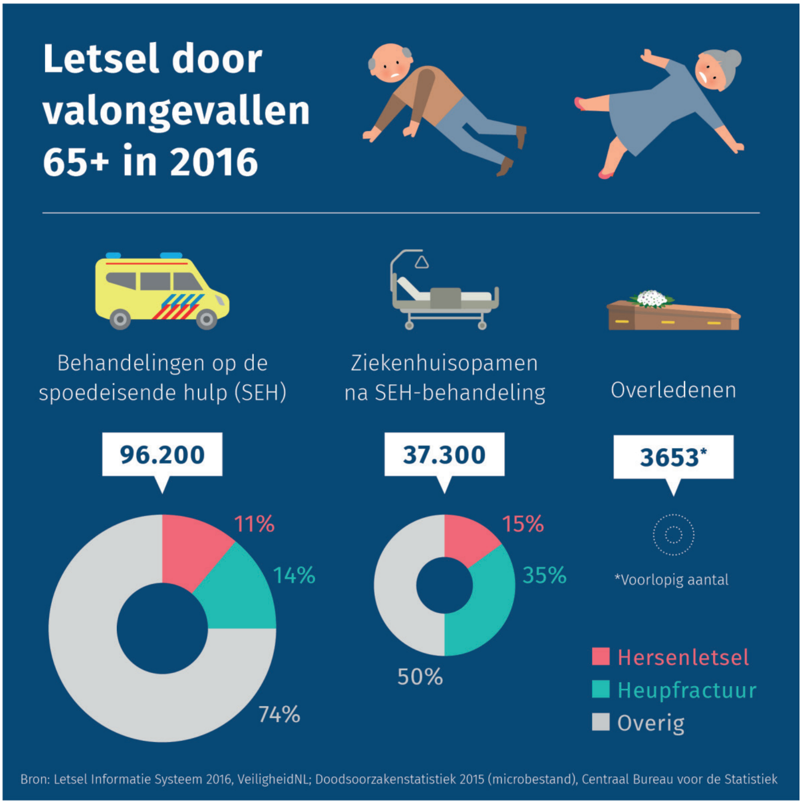

Figure 1. Fall-related injury and mortality among older adults in the Netherlands [text in Dutch] (2016).

It is clear that falls have a large impact on healthcare demands and costs, and on the quality of life of older adults. Even though this knowledge is available, no single country study has combined national data on fall-related ED visits, hospital admissions, and mortality. In this thesis, a combination is made by using several unique Dutch databases with national coverage over 20 years. This makes it possible to provide a detailed insight into fall-related healthcare use and mortality over time. Insight into differences in fall rates between countries are often hampered by methodological challenges. The Global Burden of Disease study uses the disability-adjusted life year as a measure for both mortality and morbidity. By using data of this study in the current thesis, it is possible to compare European countries over nearly 30 years, with a single metric. The knowledge that will be gathered from these studies may help to design possible future healthcare scenarios, facilitate decision-making on optimal healthcare allocation, and determine the usefulness of previous falls prevention measures.

What works to prevent falls?

At the end of 2018, the Dutch ministry of Health, Welfare and Sport has published a 'National Prevention agreement' [20]. The aim of the agreement is to get a healthier society, by focusing on prevention. The ministry's ambition is to have a society in which older adults have many healthy life years, in which they participate in society as long as possible. Falls prevention interventions could have a large supporting role in this ambition. Several interventions have been proven effective in reducing falls among community-dwelling older adults. This mainly concerns interventions with multiple components, consisting of at least an exercise component [21-25]. A recent Cochrane review reported that, if the exercise component primarily consists of balance and functional training, it is likely to reduce falls [23]. Other proven-effective components of multifactorial interventions include home modifications, medication adjustments, and vision treatments [22, 25]. Even though many effective group-based exercise programs are offered on location, older adults seem to favour individual-based programs offered in their homes [26]. This preference could be explained by the fact that group-based programs are generally more expensive, with less good accessibility [27]. Despite the fact that a lot of research has been done on the effectiveness of falls prevention interventions, not many studies have investigated the cost-effectiveness. Because financial resources in healthcare are limited, it is important that policy-makers invest in implementing cost-effective falls prevention interventions. A systematic review published in 2010 reported that, despite large methodological differences between studies, exercise interventions targeting high-risk groups offer the best value for money [28]. Since that publication, many new economic evaluation studies on falls prevention interventions have been published. Therefore, an up-to-date overview of all published economic evaluation studies and their methodological quality is provided in this thesis. This update is deemed relevant as the results can inform policy decisions.

The complexity of implementing falls prevention

Despite the existence of evidence-based falls prevention interventions, successful implementation of falls prevention remains a complex challenge [29]. One challenge concerns the role of healthcare professionals. Even though many older adults could benefit from falls prevention interventions, detection of fall risk by healthcare professionals usually only takes place if older adults express a concern about falling themselves [30]. Furthermore, healthcare professionals often lack the time and expertise to give older adults proper falls prevention advice. This is unfortunate, as it has been reported that older adults prefer healthcare professionals to take on active roles in falls prevention [31-33]. Another challenge in implementing falls prevention interventions concerns the low level of participation of older adults [34-36]. Specifically, only 21% of older adults fully adheres to their prescribed intervention [34]. Previous studies have reported numerous reasons, indicated by older adults, to not participate in falls prevention interventions. Specifically, physical barriers, such as mobility problems or poor health in general have been indicated [27, 37]. Other barriers, such as transportation difficulties, out-of-pocket costs, and a low perceived fall risk, have been indicated by older adults, as well [27, 37, 38]. Several program characteristics have been shown to improve the level of participation, such as including walking and balance exercises, and providing home visit support [34]. In addition, when evidence-based and tailored falls prevention interventions are offered to older adults, the intervention is more likely to be successful [29]. Research has shown that particularly high participation levels can lead to a reduced fall risk in older adults over time [39, 40]. Evaluating the implementation of an intervention – using different dimensions such as adoption, effectiveness, and maintenance – is valuable in translating research into practice [41]. Evaluating these dimensions makes issues related to implementation more explicit, which is sometimes ignored in a more traditional presentation of results. Few studies have evaluated the implementation of falls prevention interventions in a community setting. These studies all recognise the importance of an integrated approach, in which several different partnerships are necessary in order to successfully implement the intervention [42-44]. Furthermore, primary care providers are considered key in the recruitment of older adults [42, 44]. However, as little research in this area has been performed, it remains important to keep investigating the conditions for successful implementation of falls prevention in the community. In order to determine these conditions for a community setting in the Netherlands, it is necessary to first make an overview of the current falls prevention activities. For this thesis, a Delphi study among healthcare professionals was performed, which describes how older adults with a fall risk are detected, which falls prevention activities are used and why, and how older adults can be stimulated to participate. Furthermore, for this thesis, the *Houd ouderen op de been* study was evaluated, in which several evidence-based falls prevention interventions were implemented in the city of Breda. The conditions determined by these studies could help and guide future interventions of research projects to successfully translate into community-based programs.

Houd ouderen op de been

As many evidence-based falls prevention interventions are available in the Netherlands, but the implementation in the community remains difficult, the *Houd ouderen op de been* study was designed. Houd ouderen op de been was an observational study in which falls prevention interventions were offered in the city of Breda, in the Netherlands. Community-dwelling adults aged ≥65 years were included in the study. The aim of the study was to promote participation and improve the effectiveness of falls prevention in a community setting. For this purpose, an implementation protocol was developed, taking into account the local needs of older adults and healthcare professionals. Furthermore, evidence-based falls prevention interventions were implemented with a neighbourhood approach. The study provided insight into the impact of implementation on the level of participation, compliance, and on increasing mobility. The barriers and facilitators of implementing falls prevention were determined, as well.

Objectives

The ultimate aim of this thesis is to explore the impact and prevention of fall-related injuries among older adults. This is accomplished by first describing time trends of fall-related healthcare use and mortality, and of the burden of disease. Then, a systematic overview of economic evaluation studies on falls prevention programs is provided. Lastly, strategies for implementing falls prevention in a community setting are described and evaluated. The aims of this thesis are threefold:

1. To describe the burden over time of fall-related injury and mortality among older adults;
2. To systematically evaluate the cost-effectiveness of falls prevention programs;
3. To determine the conditions for successful implementation of falls prevention in a community setting.

Outline of the thesis

Part I (Chapter 2 and 3) covers the burden of fall-related injury and mortality among older adults. Chapter 2 provides an overview of Global Burden of Disease data on the burden of falls among older adults in 22 European countries, between 1990 and 2016. The time trends of fall-related healthcare use and mortality among older adults in the Netherlands, between 1997 and 2016, are described in Chapter 3. Part II (Chapter 4) evaluates the cost-effectiveness of falls prevention. Chapter 4 presents a systematic review on the cost-effectiveness of different falls prevention programs among older adults. Part III (Chapter 5, 6, 7, and 8) determines the conditions for successful implementation of falls prevention in a community setting. Chapter 5 describes a Delphi study on the current falls prevention activities of Dutch healthcare professionals in a community setting. The implementation of a home-based exercise program among older adults is described and evaluated in Chapter 6. Chapter 7 presents which factors are associated with frequent participation of older adults in the home-based exercise program, and it presents the effects of frequent participation on health-related outcomes over time. Chapter 8 covers the influence of personal preferences on participation levels in falls prevention programs. The main findings of Chapter 2 through 8 are discussed and interpreted in Chapter 9. Furthermore, methodological considerations, and recommendations and implications for research, policy, and practice are described.

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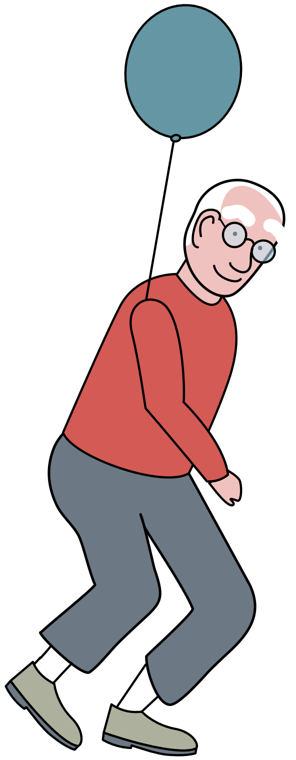
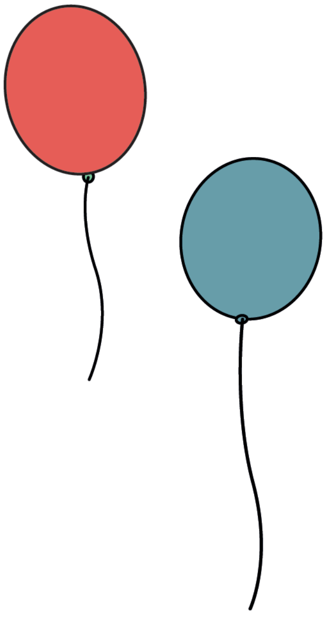


PART I

The burden of fall-related injury and mortality



CHAPTER 2

Falls in older aged adults in 22 European countries: incidence, mortality and burden of disease from 1990 to 2016

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Abstract

Introduction: Falls in older age adults are an important public health problem in the Western European region. Insight into differences in fall rates between countries can serve as important input for identifying and evaluating prevention strategies. The objectives of this paper were to provide an overview of the Global Burden of Disease (GBD) 2016 figures on mortality, incidence, and DALYs due to falls in older adults of 22 countries of the Western European region, and to examine changes over a 26 year-period.

Methods: We performed a secondary database descriptive study using the GBD 2016 results on falls in older adults aged 70 years and older in 22 countries from 1990 to 2016.

Results: In 2016 in the Western European region one in eight older adults (70+ years) sought medical treatment for a fall-related injury, ranging from one in 20 in Greece to one in five in Finland. Since 1990, DALY rates due to falls showed little change for the whole region, but patterns vary widely between countries. Some countries have lost their favourable positions due to an increasing fall-related burden of disease since 1990.

Conclusions: In conclusion, in the period 1990 to 2016 there is considerable variation in falls incidence, mortality, DALY rates and its composites in the 22 countries of the Western European region. It may be useful to assess which falls prevention measures have been taken in countries that showed continuous low or decreasing incidence, death and DALY rates despite ageing of the population.

1. Introduction

Falls are common and may lead to a large deterioration in health status among older adults. The Western European region is one of the world regions with the highest falls incidence and mortality rates in older aged adults [1]. Insight into differences in fall rates between countries can serve as important input for identifying effective prevention strategies. However, inter-country comparisons of fall rates are hampered because often different methodologies are used to assess fall rates [2-5]. Studies that did use a similar methodology focused on falls incidence or mortality [6-9]. A major shortcoming of this is that injuries resulting from falls show great variety in severity and duration and consequently using incidence or mortality rates only partially gives an indication of the population health impact of falls. A measure that includes mortality and morbidity is the disability-adjusted life year (DALY). The DALY is a composite measure that aggregates pre-mature mortality and disability into a single metric, thus, providing a more comprehensive measure of the relative health impact of public health problems compared to mortality or incidence figures alone [10]. A landmark study that used the DALY is the Global Burden of Disease and Injury (GBD) study. The GBD study annually quantifies mortality, incidence, prevalence and DALYs for over 300 diseases and causes of injury of 195 countries and territories using a standardized and systematic approach [11-15]. This strategy results in internally consistent and comparable estimates, both between populations and over time. We present the GBD 2016 figures on mortality, incidence, DALYs and its components of falls in adults aged 70 years and older in 22 countries of the Western European region, and trends between 1990 and 2016.

2. Materials and methods

We analysed levels and trends of incidence, mortality, and DALY and its components years of life lost (YLL), and years lived with disability (YLD) of falls injury in adults aged 70 years and older in the Western European region of the GBD 2016 study. The overall GBD 2016 study provided global and regional estimates for 333 diseases and injuries for 23 age groups, both sexes, and 195 countries and territories from 1990 to 2016 [12] Detailed descriptions of the methodology and approach of the GBD study and supplemental information on methods that were used to arrive at the incidence, mortality, YLL, YLD and DALY estimates have been published elsewhere [1, 13, 16, 17]. For the present study, we used the GBD 2016 interactive data visualization tool 'GBD Compare' to retrieve the estimates for falls incidence, mortality, YLLs, YLDs, and DALYs of older adults (GBD 2016 Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2016; http://vizhub.healthdata.org/gbd-compare/). We used final fits for each year in the period 1990 to 2016. We compared both total numbers and rates of falls incidence, mortality, YLD, YLL and DALY by age-category (70-74, 75-80, 80-84, 85-90, 90-94 and 95+), by sex, by country and over time. The 70+ rates by country and by year were age standardized within the 70+ age group.

2.1 Western European region - countries

In GBD 2016 Europe is divided into three regions: the Central European region (13 countries), the Eastern European region (7 countries), and the Western European region (22 countries). The following countries were included in the Western European region of the GBD: Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

2.2 GBD falls injury classification

Injury incidence and mortality data coded according to the International Classification of Diseases, Ninth Revision (ICD-9), and The International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) were categorized into mutually exclusive and collectively exhaustive GBD nature-of-injury categories [1, 12]. The detailed list of ICD-9 and ICD-10 codes was provided elsewhere [16]. Falls injury incidence and death were defined as in ICD-9 codes E880-888 and E929.3 and ICD-10 codes W100-W19. Morbidity analysis was restricted to cases warranting some form of health care. This includes injury cases of sufficient severity to require inpatient care if there are no restrictions in access to health care and injury cases of sufficient severity to require health care attention but not hospitalization [1]. This category latter category includes emergency department and GP visits [1].

2.3 Uncertainty

The GBD estimates have varying degrees of uncertainty in the input data, the data adjustments and the statistical models used to estimate values for all countries over time. Standard GBD methodology is that for each component (incidence, mortality, YLD, YLL and DALY), uncertainty from each source is propagated at the level of 1,000 draws, i.e. all estimates are calculated 1,000 times each time drawing from distributions.

3. Results

3.1 Mortality and incidence

In 2016 in the Western European region among older adults aged 70+ years the incidence of sustaining an injury that warranted some form of health care was 12.1 million (uncertainty interval (UI) 10.9-13.5 million), of which 7.9 million (65.1%; UI 6.8-9.2 million) were due to falls. In 2016 51,026 (UI 40,177-55,674) older adults died due to falls. The incidence rate of falls increased substantially by age, with an incidence rate of 5,482 (UI 4,016-7,289) per 100,000 in age category 70-74y to 47,902 (UI 34,672-61,786) per 100,000 in age category 95+y. For death due to falls this increase was even more pronounced with death rates ranging from 17 (UI 12-19) per 100,000 in age category 70-74 to 656 (UI 475-731) per 100.000 in age category 95+. The incidence rate of falls was higher in females than in males; however, death rates in older adults were slightly, but not significantly, higher in males. Incidence rates of falls in older adults varied widely by country, with lowest incidence rates in Greece (5,840 per 100,000 (UI 4,878-7,155)) and Portugal (8,433 per 100,000 (UI 7,007-10,236)) and highest incidence rates in Belgium (19,276 per 100,000 (UI 16,282-23,151)) and Finland (21,009 per 100,000 (UI 17,817-24,857)). Death rates were also lowest in Greece (30 per 100,000 (UI 21-69)) and Portugal (43 per 100,000 (UI 34-81)) and highest in Norway (142 per 100,000 (UI 75-170)) and Switzerland (142 per 100,000 (UI 98-175)). The case fatality rate (the death rate/incidence rate) was highest in Cyprus (0.81%) and the Netherlands (0.99%); almost twice as high compared to the countries with lowest case fatality rates (Portugal (0.50%) and Greece (0.52%)). Table 1 shows the incidence and death rates of falls in older adults by country.

Table 1.
Incidence and death rates of falls in older adults (70+) per 100,000 by country with 95% uncertainty intervals, 2016.

Country	Incidence rate (per 100,000)	Rank number incidence rate	Death rate (per 100,000)	Rank number death rate	Percent of total deaths[$]
Andorra	13150 (11050 - 15617)	10	80.0 (58.6 - 106.0)	12	1.5%
Austria	14787 (12400 - 17517)	8	93.7 (83.1 - 114.9)	9	1.8%
Belgium	19276 (16282 - 23151)	2	116.8 (89.2 - 133.3)	6	2.0%
Cyprus	9664 (7858 - 11495)	18	78.2 (68.9 - 87.6)	13	1.3%
Denmark	14905 (12358 - 18075)	7	92.1 (52.4 - 110.3)	10	1.7%
Finland	21009 (17817 - 24857)	1	130.8 (83.6 - 152.3)	4	2.5%
France	18601 (15646 - 22127)	5	135.2 (99.8 - 153.2)	3	2.6%
Germany	12736 (10513 - 15362)	11	77.5 (61.0 - 87.0)	14	1.5%
Greece	5840 (4878 - 7155)	22	30.4 (21.2 - 68.9)	22	0.5%
Iceland	11207 (9189 - 13306)	15	88.1 (66.7 - 100.5)	11	1.6%
Ireland	10131 (8460 - 12288)	17	56.2 (47.3 - 78.3)	18	1.0%
Israel	8883 (7461 - 10393)	20	49.3 (38.9 - 58.7)	20	0.9%
Italy	12166 (10287 - 14279)	12	72.1 (60.7 - 81.5)	16	1.3%
Luxembourg	15827 (13039 - 18947)	6	108.5 (91.1 - 125.4)	7	2.1%
Malta	10786 (8805 - 12984)	16	66.8 (55.5 - 80.2)	17	1.4%
Netherlands	12014 (10354 - 13814)	13	119.1 (54.9 - 145.5)	5	2.1%
Norway	18940 (15904 - 22452)	3	141.7 (75.2 - 170.3)	2	2.5%
Portugal	8433 (7007 - 10236)	21	42.6 (33.6 - 80.6)	21	0.7%
Spain	9519 (7970 - 11533)	19	51.2 (43.7 - 77.1)	19	1.0%
Sweden	13841 (11576 - 16176)	9	101.1 (55.5 - 121.1)	8	1.8%
Switzerland	18823 (16475 - 22178)	4	142.1 (97.7 - 175.1)	1	2.9%
United Kingdom	11620 (9861 - 13464)	14	75.5 (52.7 - 82.1)	15	1.3%

[$] Percent of total deaths is the relative contribution of falls deaths to the total DALYs of all causes in the population aged 70 and older.

3.2 Burden of disease

In 2016 the total burden of disease due to injuries in older adults in the Western European region was 2.3 million DALYs (UI 1.9-2.8 million), of which 1.2 million DALYs (53.9%; UI 0.97-1.5 million) were due to falls. YLLs were responsible for 32.7% of falls DALYs (403,144 YLLs (UI 315,752-434,420)) and YLDs for 67.3% of falls DALYs (830,906 YLDs (UI 590,066-1,137,823)). The DALY, YLL and YLD rates increased with age. Table 2 shows the DALY, YLL and YLD rates per country. DALY rates of falls in older adults were lowest in Greece (1,230 DALYs per 100,000 (UI 900-1,686) and Portugal (1,396 DALYs per 100,000 (UI 1,057-1,873)) and highest in Belgium (2,860 DALYs per 100,000 (UI 2,244-3,585)) and Finland (3,108 per 100,000 (UI 2,374-3,926). The relative contribution of falls DALYs to the total DALYs of all causes in the population aged 70 and older was highest in France (4.1%), Switzerland (4.1%) and Finland (4.3%).

Table 2. DALY, YLD and YLL rates of falls in older adults (70+) per 100,000 by country with 95% uncertainty intervals, 2016.

Country	YLD rate (per 100,000)	YLL rate (per 100,000)	DALY rate (per 100,000)	Rank number DALY rate	Percent of total DALYs$
Andorra	1389 (984 - 1882)	601 (440 - 798)	1990 (1530 - 2501)	12	2.8%
Austria	1581 (1125 - 2149)	788 (689 - 952)	2369 (1874 - 2992)	7	3.3%
Belgium	1926 (1381 - 2617)	934 (678 - 1072)	2860 (2244 - 3585)	2	3.6%
Cyprus	1147 (812 - 1579)	655 (576 - 737)	1802 (1445 - 2216)	17	2.2%
Denmark	1431 (1026 - 1947)	709 (434 - 845)	2140 (1638 - 2705)	9	2.8%
Finland	2039 (1461 - 2773)	1069 (647 - 1263)	3108 (2374 - 3926)	1	4.3%
France	1788 (1265 - 2436)	979 (719 - 1111)	2766 (2189 - 3440)	4	4.1%
Germany	1342 (944 - 1832)	669 (512 - 760)	2011 (1577 - 2518)	11	2.6%
Greece	962 (681 - 1311)	268 (195 - 557)	1230 (900 - 1686)	22	1.6%
Iceland	1236 (876 - 1689)	691 (527 - 789)	1928 (1529 - 2408)	13	2.6%
Ireland	1272 (900 - 1734)	483 (403 - 656)	1755 (1348 - 2262)	18	2.3%
Israel	1043 (734 - 1421)	378 (298 - 458)	1421 (1097 - 1816)	20	1.9%
Italy	1299 (923 - 1772)	559 (474 - 635)	1858 (1461 - 2348)	15	2.5%
Luxembourg	1518 (1072 - 2064)	879 (736 - 1028)	2398 (1919 - 2987)	6	3.3%
Malta	1234 (873 - 1690)	603 (495 - 741)	1836 (1441 - 2305)	16	2.5%
Netherlands	1187 (839 - 1622)	914 (437 - 1115)	2100 (1435 - 2626)	10	2.7%
Norway	1674 (1189 - 2300)	1035 (568 - 1247)	2709 (1982 - 3409)	5	3.7%
Portugal	1021 (726 - 1392)	375 (301 - 677)	1396 (1057 - 1873)	21	1.8%
Spain	1167 (823 - 1594)	412 (356 - 594)	1579 (1217 - 2035)	19	2.3%
Sweden	1394 (990 - 1900)	777 (435 - 928)	2171 (1595 - 2750)	8	2.9%
Switzerland	1736 (1239 - 2374)	1073 (736 - 1344)	2809 (2194 - 3535)	3	4.1%
United Kingdom	1263 (902 - 1725)	598 (414 - 649)	1861 (1434 - 2344)	14	2.4%

$ Percent of total DALYs is the relative contribution of falls DALYs to the total DALYs of all causes in the population aged 70 and older.

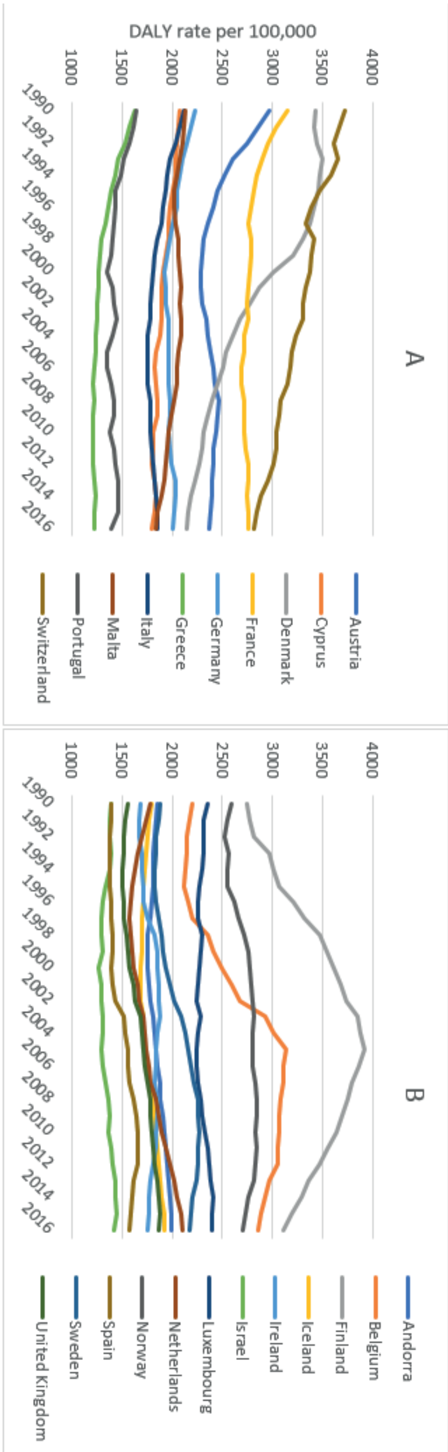
3.3 Changes in burden of disease, 1990-2016

The number of DALYs due to falls in older adults increased by 54%, from 800,929 DALYs (UI 655,581-987,049) in 1990 to 1,234,050 DALYs (UI 973,591-1,545,404) in 2016. However, the rate of DALYs due to falls showed little change over time from 2,156 DALYs per 100,000 (UI 1,764-2,656) in 1990 to 2,051 DALYs per 100,000 (UI 1,618-2,568) in 2016. Trends in DALY rates of falls in older adults over the period from 1990 to 2016 vary widely, from large decreases in Denmark (-37.5%), Greece (-24.6%), Switzerland (-24.4%) and Austria (-20.4%) to large increases in Belgium (30.1%), the UK (19.2%), the Netherlands (18.0%) and Sweden (15.5%). This resulted in countries losing their favourable positions compared to other countries in the Western European region. Finland stands out because DALY rates of falls in older adults rapidly increased from 1990 to 2005, followed by a decline. A similar, but less pronounced, pattern is seen in Belgium. Figure 1 shows the DALY rate per country from 1990 to 2016. Table 3 shows the 1990 falls DALY rates and percent of change.

Table 3. DALY rates and percent of change[$] of falls in the elderly (70+) per 100,000 by country.

Country	DALY rate per 100,000 in 1990	Rank number DALY rate 1990	Percent of change[$] (1990-2016)
Andorra	1847 (1390 - 2370)	14	7.7%
Austria	2975 (2441 - 3624)	4	-20.4%
Belgium	2199 (1759 - 2790)	9	30.1%
Cyprus	2071 (1683 - 2496)	12	-13.0%
Denmark	3426 (2085 - 4340)	2	-37.5%
Finland	2752 (2206 - 3382)	5	-37.5%
France	3146 (2540 - 3838)	3	-12.1%
Germany	2223 (1809 - 2740)	8	-9.6%
Greece	1630 (1283 - 2095)	19	-24.6%
Iceland	1802 (1459 - 2243)	15	7.0%
Ireland	1680 (1361 - 2091)	17	4.5%
Israel	1396 (1132 - 1725)	21	1.8%
Italy	2113 (1718 - 2616)	11	-12.0%
Luxembourg	2351 (1892 - 2973)	7	2.0%
Malta	2129 (1728 - 2604)	10	-13.8%
Netherlands	1780 (1411 - 2191)	16	18.0%
Norway	2588 (1898 - 3190)	6	4.7%
Portugal	1642 (1254 - 2219)	18	-15.0%
Spain	1394 (1057 - 1899)	22	13.2%
Sweden	1880 (1464 - 2326)	13	15.5%
Switzerland	3719 (2787 - 4533)	1	-24.5%
United Kingdom	1562 (1254 - 1959)	20	19.2%

[$] The percent of change is the percentage change in DALY rate in the period from 1990 to 2016. A positive percentage of change indicates an increase; a negative annualized percentage of change indicates a decrease.



A: Countries with a decrease of DALY rate between 1990 and 2016

B: Countries with an increase in DALY rate between 1990 and 2016

Figure 1. DALY rate of falls in older adults per 100,000 per country in the period from 1990 to 2016.

3.4 Changes in incidence, YLD and YLL, 1990-2016

Between 1990 and 2016 falls YLL rates declined significantly by 20.6%, respectively, whereas falls YLD rates showed little change (not significant increased by 5.3%), indicating a shift towards YLD as the primary driver of falls DALYs in older adults. This shift was apparent for most countries, but not at the same rate. The ratio of the composites of the DALY over time for the 22 countries is shown in Supplementary Figure S1. Largest increases in YLD/DALY ratio were found in Ireland (1990: 61%; 2016: 72%), Cyprus (1990: 52%; 2016: 64%) and Denmark (1990: 52%; 2016: 67%). In two countries the YLD/DALY ratio decreased between 1990 and 2016, namely Iceland (1990: 65%; 2016: 64%) and the Netherlands (1990: 59%; 2016: 56%). The Netherlands also stands out for the relatively low YLD/DALY ratio in the period from 2000 to 2016. Spain, Portugal and Greece stand out because of their relatively high YLD/DALY ratio.

4. Discussion

Incidence, mortality and DALY rates of falls in the older adults varied widely by Western European country. There was a fourfold difference in death rates due to falls between the countries with lowest and highest falls death rates. For incidence and DALY rates the difference between countries with highest and lowest rates was three- and twofold, respectively. The falls death and incidence rates in older adults from the GBD 2016 study are higher compared to those reported by previously published studies [2, 3, 8, 18-21]. These differences in incidence and mortality rates may be explained by broader age ranges included in the previously published studies. Typically, incidence and mortality rates of falls in older adults increases with age and we have restricted our study to the age category 70 years and older rather than 60 or 65 years and older, which may have led to higher incidence and mortality rates. A second explanation for the difference in incidence rates may be that a different case definition was applied. Often studies reported incidence rates of cases admitted to hospital, whereas the GBD analysis covers cases warranting some form of health care in a system. This includes patients who visited the Emergency Department due to falls. A Belgian study that assessed the incidence of falls in older adults and that included primary care visits and emergency department reported falls injury incidence rates similar to the GBD [22]. Third, the GBD corrects for ill-defined and unknown causes of death in cause-of-deaths registries [16]. Ill-defined deaths can be subdivided into two categories: general ill-defined and unknown cause death (e.g. R99 Ill-defined and unknown cause of mortality) and injury ill-defined cause of death (e.g. X59 Exposure to unspecified factor). Both types of ill-defined and unknown causes of death were proportionally redistributed on all injury codes, including falls [16]. For specific nature of injury codes such as falls redistribution of general ill-defined and unknown deaths leads to a small number of redistributed deaths and subsequently a small increase in death rates. The second category of ill-defined and unknown deaths will be redistributed within injury causes only, hence redistribution of this category of ill-defined and unknown deaths will proportionally lead to a higher increase in fall death rates. The total increase of fall death rates (and other nature of injury categories) depends on the total percentage of ill-defined and unknown deaths in cause of death registries and this percentage varies by country and by year. An important finding of this study is that since 1990 DALY rates due to falls showed little change for the whole region, but patterns varied widely between countries. In Denmark, Finland, Greece, Switzerland and Austria the burden of falls injury in older adults decreased substantially, whereas other countries (e.g. the UK, Netherlands, Sweden) have lost their favourable positions due to an increasing fall-related burden of disease since 1990. Researchers have identified several main risk factors for falls in the older adults and the combination of each of these risk factors may vary by country and over time, making it difficult to unravel which prevention measures have yielded the largest effect [6, 23]. Nevertheless, it may be useful to assess which falls prevention measures have been taken in countries that showed continuous low or decreasing incidence, death and DALY rates despite ageing of the population. If rates of falls in the elderly can be lowered to those of countries with lowest levels in 2016, potentially 821 DALYs per 100,000 could be averted in the Western European region. A second important finding is that the YLL rates decreased significantly, whereas YLD rates showed little change over time, indicating a shift towards YLD as the primary driver of falls DALYs in older adults. The rate of this shift varied tremendously between countries. The shift towards YLD may be the result of improved access to better quality care after sustaining an injury or by falls prevention measures that resulted in a reduction of the severity of injury sustained due to a fall. Another explanation may be that frailty, a major risk factor of falls in older adults, and co-morbid disease and disabilities occur at higher ages compared to 1990, resulting in a shift off falls incidence and mortality towards the very old ages [12, 23].

4.1 Limitations

The death rate estimates in Western European countries were based on complete vital registration systems; however, nationally representative incidence data on falls were available for five countries only (Belgium, Finland, the Netherlands, Portugal and Switzerland). Incidence estimates for every Western European country were made by using statistical models that borrow strength over time and geography, but these estimates are inherently less precise for countries without national representative incidence data [17].

The European Hospital Morbidity Database was an important data source for the five countries for which nationally representative injury incidence data was available. However, these data were available only in tabular form and oftentimes the European Hospital Morbidity Database registered nature of injury categories as underlying cause of injury, making it impossible to derive incidence by the actual cause of injury (e.g. falls). The GBD estimates for injuries would be greatly strengthened if hospital data were made available in microdata form and with multiple diagnosis fields. The Netherlands was the only country that provided Emergency Department data on injuries, but this information is most probably available for many Western European countries as well. Availability of cause and nature of injury coded Emergency Department data for other countries will also improve the GBD injury estimates greatly. A second limitation of this study is that the DALY estimates were based on prevalence based data. DisMod-MR is used to estimate prevalence from incidence and this process assumes a steady state where rates are not changing over time. This steady state assumption may lead to inaccurate estimates of prevalence of long-term disability if there are large trends in incidence rates or mortality.

5. Conclusion

In conclusion, there is considerable variation in incidence, mortality and DALY rates of falls in older adults in the 22 countries of the Western European region. Since 1990, the burden of disease of falls showed little change in the whole region, but patterns vary between countries. It may be useful to assess which falls prevention measures have been taken in countries that showed continuous low or decreasing incidence, death and DALY rates despite ageing of the population.

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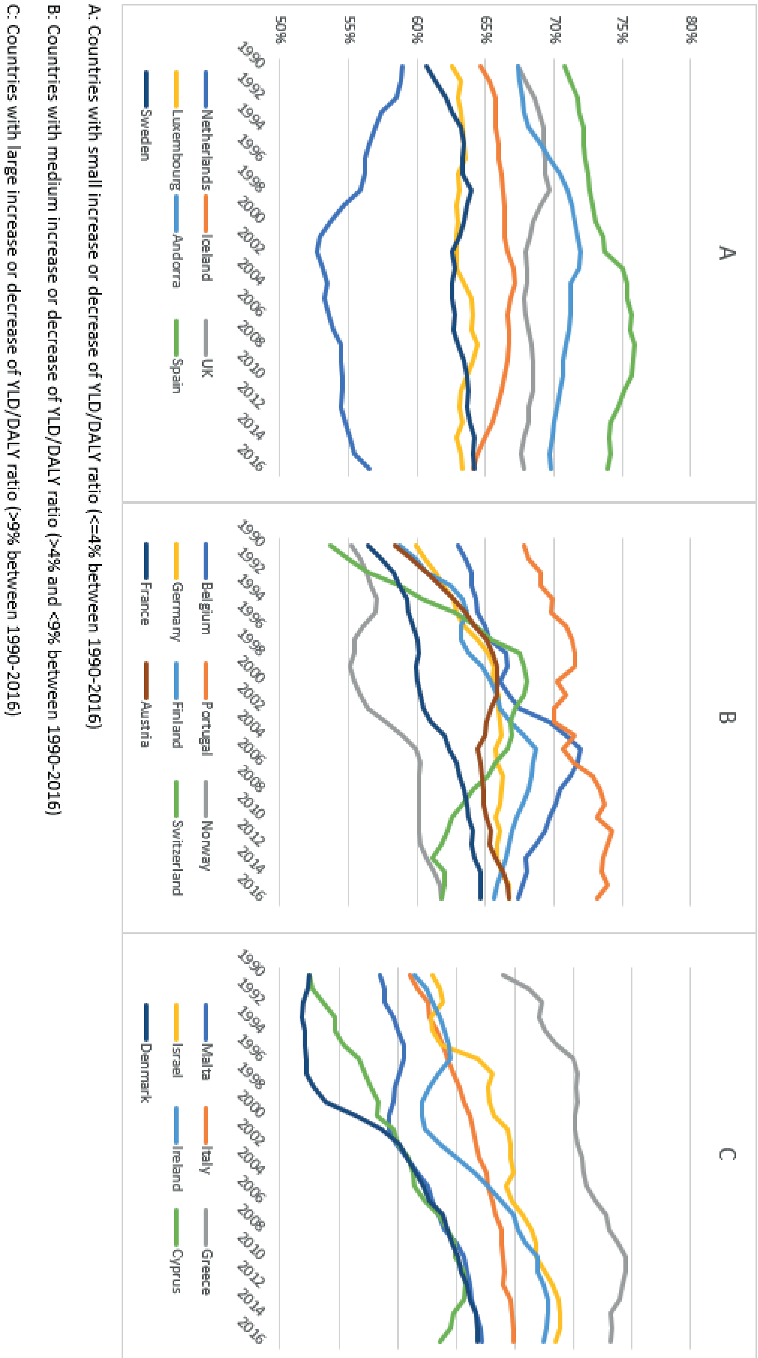
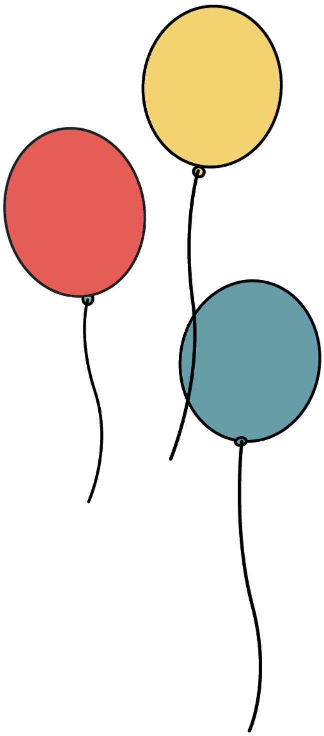
7. Supplementary material



Supplementary Figure S1. YLD/DALY ratio of falls in older adults by country, 1990-2016.



CHAPTER 3

Fall-related healthcare use and mortality among older adults in the Netherlands, 1997-2016

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Abstract

Objectives: Fall-related injuries are a leading cause of morbidity among older adults, leading to a high healthcare consumption and mortality. We aim to describe and quantify time trends of fall-related healthcare use and mortality among adults aged ≥65 years in the Netherlands, 1997–2016.
Design: Data were extracted from the Dutch Injury Surveillance System, Dutch Hospital Discharge Registry, and Cause-of-Death Statistics Netherlands, by age, sex, diagnosis, injury location, and year.
Measurements: Absolute numbers and age-standardized rates of fall-related Emergency Department (ED) visits, hospital admissions, and fatalities, as well as average length of hospital stay (LOS) were calculated.
Results: Between 1997 and 2016, absolute numbers of fall-related ED visits increased by 48%, hospital admissions increased by 59%, and mortality showed an almost threefold increase. These absolute numbers doubled among adults aged ≥85 years. A shift in fall-related injury diagnosis was observed over the years with a growing share of skull/brain injuries. In contrast to the increase in absolute numbers, standardized incidence rates of ED visits decreased by 30% ($p=0.00$), whereas incidence rates of hospital admissions and mortality did not significantly change over time. Furthermore, the absolute number of hospital admission days almost halved, due to a reduced average LOS from 18.5 (95% confidence interval (CI): 18.2–18.8) days (1997) to 6.1 (95% CI, 6.1–6.2) days (2016).
Conclusion: Even though the standardized incidence rates of ED visits decreased in the past twenty years, the absolute number of fall-related ED visits increased. The number of hospital admissions has also increased, but the total number of admission days has almost halved during the same period. If the observed trends would continue, this may have implications for healthcare resource allocation, as the burden of care in EDs increases, and the admission duration reduces.

3

1. Introduction

Fall-related injuries are a leading cause of morbidity among older adults, consequently leading to Emergency Department (ED) visits, hospital admissions and fatalities worldwide [1-9]. The ED visits and hospital admissions have a major impact on healthcare costs. Namely, an estimated $10 billion ($31 per capita) is spent yearly in the United States [10], and an estimated $570 million ($34 per capita) is spent yearly on the cost of falls in the Netherlands (2017 US$) [11]. Globally, an increase in these fall-related injury costs over time is expected, due to an ageing society. Studies from multiple countries have shown that absolute numbers of fall-related ED visits [9], hospital admissions [2, 5, 7], and fatalities [1, 3, 6, 8] increased in the past decades. On the contrary, research in the Netherlands has also shown that the average length of hospital stay (LOS) after a fall-related injury decreased [5]. Even though previous studies have investigated time trends, to our knowledge, no single country study has so far combined national data on fall-related ED visits, hospital admissions, and mortality. Combining these data provides detailed insight into the fall-related healthcare use and mortality by age, diagnosis, and location of injury on a national level. This may help design possible future healthcare scenarios and facilitate decision-making on optimal healthcare allocation. The aim of this study is to describe and quantify time trends of fall-related ED visits, hospital admissions, and fatalities among adults aged ≥65 years in the Netherlands, from 1997 to 2016.

2. Materials and methods

2.1 Data sources

Individuals aged ≥65 years with unintentional fall-related injury or mortality were included in the study. Fall-related injury was defined by the International Classification of Diseases (ICD) 10th revision [12], by W00-W19, and by X59 (i.e. slipping, tripping, and stumbling). Fall-related data on ED visits from 1997 to 2016 were extracted from the Dutch Injury Surveillance System (DISS). From 1997 onwards, the DISS records statistics of individuals treated for injuries at, on average, fourteen (range 12–17) geographically distributed EDs, representing 12–15% of the ED visits in the Netherlands. This includes general, teaching, and University hospitals that provide a 24-hour medical emergency service. The DISS data of fourteen EDs is enough of a representative sample to extrapolate to national estimates, as among others, the age distribution, the level of the hospital, and the degree of urbanization of the ED sample is representative to all EDs in the Netherlands [13-16]. Supplementary Text S1 provides additional information on how the extrapolation calculation was performed [17]. The absolute number, incidence rate, injury diagnosis, and injury location were extracted from DISS. Data on hospital admissions due to fall-related injuries were extracted from the Dutch Hospital Discharge Registry (HDR). This registry collects hospital data of almost all hospitals in the Netherlands with a uniform classification system and with a high national coverage (missing values <10%). A correction is performed by The Consumer and Safety Institute in order to extrapolate the high national coverage to full national coverage for each year (Supplementary Text S1) [17]. The absolute number, incidence rate, injury diagnosis, and injury location were extracted from the HDR. The absolute number of hospital admission days was extracted from the HDR and the average LOS was calculated by dividing the absolute number of fall-related hospital admission days by the absolute number of fall-related hospital admissions. For the average LOS, a 95% confidence interval (CI) was calculated, as well. Data on fall-related mortality was obtained from Cause-of-Death Statistics Netherlands [18]. Statistics

Netherlands collects mortality data with a uniform classification system, based on official death certificates of all deceased inhabitants and non-inhabitants in the Netherlands. The absolute number of fall-related fatalities and fall-related mortality rates were extracted from Statistics Netherlands.

2.2 Data analysis

Absolute numbers and crude incidence rates of fall-related ED visits, and hospital admissions, covering the whole Dutch population, were specified for age, sex, injury diagnosis, and location of injury for each year (1997–2016). Fall-related fatalities were specified for age and sex for each year. The following age groups were defined: 65–74, 75–84, and ≥85 years. Absolute number of hospital admission days and average LOS were specified for age, sex, and injury diagnosis for each year. Age-standardized incidence rates of fall-related ED visits and hospital admissions were expressed per 10,000 individuals, whereas fall-related fatalities were expressed per 100,000 individuals. Standardized incidence rates were calculated by direct standardization [19]. Between 1997 and 2016, the Dutch population aged ≥65 years increased by 147% to about 3 million [18]. This increase was highest among adults aged ≥85 years. The mean age of fall-related patients increased, as well, from 78.5 years in 1997 to 79.6 years in 2016. In order to correct for these demographic changes, age-specific rates were weighted using a standard age distribution of 2016. Data on demographic changes were obtained from Statistics Netherlands [18]. To analyse the statistical significance of the percentage annual change over time of standardized incidence rates, a Joinpoint regression model was used [20]. A p-value < 0.05 was considered statistically significant. All analyses were performed using Joinpoint Regression Program, Version 4.6.0.0 – April 2018; Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute.

3. Results

3.1 Fall-related Emergency Department visits

From 1997 until 2016, the absolute number of fall-related ED visits among adults aged ≥65 years increased by 48%, from 64,800 in 1997 to 96,200 in 2016 (Fig. 1a). The ED visits among adults aged ≥85 years more than doubled over time (Table 1). Fractures were most commonly diagnosed after a fall. Furthermore, a shift in the fall-related injury diagnosis pattern was observed, as the diagnosis of skull/brain injury increased by almost a tenfold. Over time, changes have also occurred in the location of the fall. Specifically, absolute numbers of falls in and around the house have increased from 1997 to 2016, whereas falls on the street, without involvement of other road users, decreased. In contrast to a general increase in absolute numbers of fall-related ED visits, the standardized incidence rates decreased by 30% in the past two decades, from 455 per 10,000 in 1997, to 320 per 10,000 in 2016 ($p=0.00$) (Table 1). A reduction was observed among all age groups, and regardless of injury diagnosis or location of injury. However, standardized incidence rates of skull/brain injuries and other injuries significantly increased over time. Skull/brain injuries increased by almost a threefold, from 10 per 10,000 in 1997, to 37 per 10,000 in 2016 ($p=0.00$).

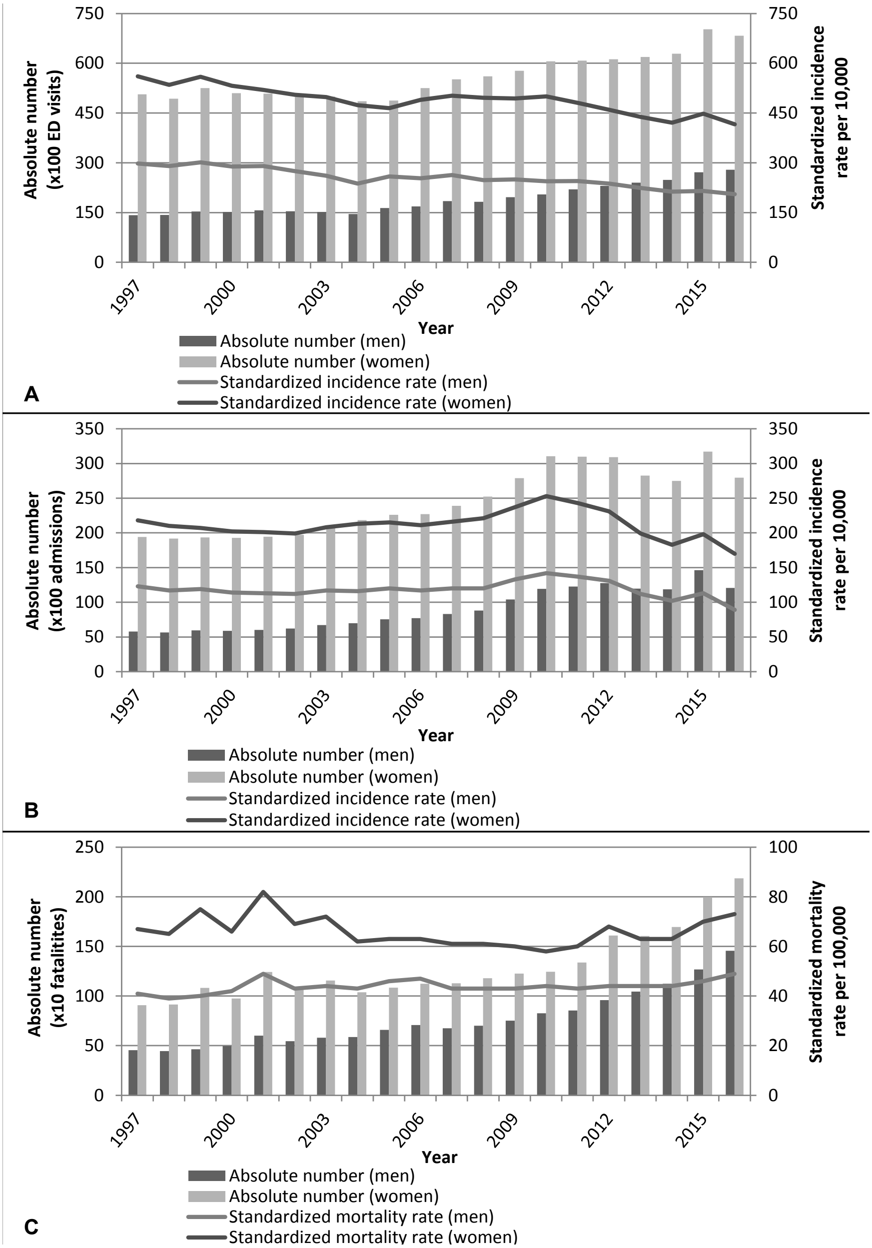

Figure 1. Absolute number and standardized incidence rates of fall-related Emergency Department visits (A), fall-related hospital admissions (B), and fall-related mortality (C), for men and women aged ≥65 years in the Netherlands, 1997-2016.

Table 1. Absolute number, standardized incidence rates, injury diagnosis, and injury location of fall-related Emergency Department visits among adults aged ≥65 years in the Netherlands, 1997-2016.

	1997	2001	2005	2009	2013	2016	p-value*
Absolute number of Emergency Department visits							
≥65 yr	64,810	66,565	65,158	77,323	85,888	96,186	n.a.
65-74 yr	26,317	25,344	24,209	28,936	31,283	34,773	n.a.
75-84 yr	23,442	25,396	24,345	26,653	27,870	29,907	n.a.
≥85 yr	15,051	15,825	16,604	21,734	26,735	31,506	n.a.
Standardized incidence rate per 10,000 population							
≥65 yr	455	426	379	389	343	320	0.00
65-74 yr	320	302	268	281	228	202	0.00
75-84 yr	458	428	359	358	337	320	0.00
≥85 yr	1,211	1,075	1,030	1,015	920	915	0.00
Injury diagnosis (absolute number)							
Skull/brain injury	1,321	1,667	2,228	4,684	6,145	11,060	n.a.
Fractures	36,775	37,904	38,168	46,076	52,943	54,281	n.a.
Superficial injuries	14,483	15,260	13,857	15,152	13,943	12,633	n.a.
Wounds	5,493	5,481	5,206	4,594	5,029	4,734	n.a.
Luxations, distortions	4,142	4,630	3,938	4,685	5,102	5,125	n.a.
Other injury	2,596	1,624	1,761	2,133	2,724	8,359	n.a.
Injury diagnosis (standardized incidence rate per 10,000 population)							
Skull/brain injury	10	11	13	24	25	37	0.00
Fractures	256	240	220	230	211	181	0.00
Superficial injuries	102	98	81	77	56	42	0.00
Wounds	40	36	31	23	20	16	0.00
Luxations, distortions	29	29	23	24	20	17	0.00
Other injury	18	11	11	11	11	28	0.00
Location of injury (absolute number)							
In and around home	28,734	27,150	28,309	38,001	47,161	49,296	n.a.
In a nursing home	4,787	4,585	5,546	6,591	9,469	8,259	n.a.
On the street	12,347	10,240	9,179	11,519	11,275	10,016	n.a.
Other location	18,944	24,588	22,125	21,211	17,984	28,616	n.a.
Location of injury (standardized incidence rate per 10,000 population)							
In and around home	202	173	164	190	188	164	0.08
In a nursing home	36	31	33	33	38	27	0.11
On the street	84	64	53	58	45	33	0.00
Other location	133	158	129	108	72	95	0.38

yr, years; *, percentage annual change over time of standardized incidence rates; a p-value <0.05 is considered statistically significant.

3.2 Fall-related hospital admissions

The absolute number of fall-related hospital admissions increased by 59%, from 25,200 in 1997 up to 40,000 in 2016 (Fig. 1b). These absolute numbers almost doubled among adults aged ≥85 years (Table 2). In 2016, almost half of the adults aged ≥85 years were admitted to the hospital after a fall-related ED visit. Comparable to the injury diagnosis of fall-related ED visits, fractures were most often observed in fall-related hospital admissions, whereas absolute numbers of the diagnosis of skull/brain injuries had the greatest increase over time. In contrast to ED visits, absolute numbers of older adults who fell on the street and who subsequently needed to be admitted to the hospital, did not decrease during the same period. There was no significant overall change in the standardized incidence rates of fall-related hospital admissions throughout the years, except among adults aged ≥85 years. In this age group, incidence rates decreased by 31% from 647 per 10,000 in 1997 to 445 per 10,000 in 2016 ($p=0.00$) (Table 2). In terms of injury diagnosis, standardized incidence rates increased slightly in skull/brain injury ($p=0.01$), but decreased in hip fractures ($p=0.00$). A reduction in incidence rates was observed in fall-related injury occurring in a nursing home ($p=0.00$) and on other locations ($p=0.00$). Fig. 2 provides an overview of the absolute number of hospital admissions, absolute number of hospital admission days, and the average LOS per patient. It shows that, despite an increased absolute number of hospitalizations, the absolute number of admission days almost halved, from 439,000 days in 1997, to 245,100 days in 2016. During the same period, the average LOS per patient decreased from 18.5 (95% CI:18.2–18.8) to 6.1 (95% CI: 6.1–6.2) days. The decreasing trend was observed among men and women, and among all age groups. Adults aged≥85 years had the greatest reduction in LOS over time. In terms of injury diagnosis, hip fractures had the largest average LOS decrease, from 21.6 (95% CI: 21.2–21.9) days in 1997, to 7.5 (95% CI: 7.4–7.6) days in 2016. Skull brain injuries showed a decreasing trend in average LOS as well, from 10.5 (95% CI: 9.4–11.5) days in 1997, to 5.6 (95% CI: 5.3–5.9) days in 2016.

Table 2. Absolute number, standardized incidence rates, injury diagnosis, and injury location of fall-related hospital admissions among adults aged ≥65 years in the Netherlands, 1997-2016.

	1997	2001	2005	2009	2013	2016	p-value*
Absolute number of hospital admissions							
≥65 yr	25,189	25,474	30,168	38,313	40,235	40,012	n.a.
65-74 yr	7,732	7,149	8,534	11,355	11,884	12,116	n.a.
75-84 yr	9,413	9,921	11,686	13,407	13,380	12,587	n.a.
≥85 yr	8,044	8,404	9,948	13,551	14,971	15,309	n.a.
Stanardized incidence rate per 10,000 population							
≥65 yr	180	165	175	192	160	133	0.27
65-74 yr	94	85	93	109	86	70	0.34
75-84 yr	186	169	172	182	162	135	0.17
≥85 yr	647	572	617	617	516	445	0.00
Injury diagnosis (absolute number)							
Skull/brain injury	1,029	1,063	1,963	3,639	3,576	3,411	n.a.
Hip fracture	12,106	14,072	14,612	15,678	14,507	15,244	n.a.
Fracture upper extremities	2,294	2,548	3,790	5,381	4,966	5,057	n.a.
Other fracture	4,278	4,051	4,942	6,415	6,888	8,822	n.a.
Other injury	4,021	3,919	4,973	7,234	10,525	7,478	n.a.
Injury diagnosis (standardized incidence rate per 10,000 population)							
Skull/brain injury	8	7	12	19	15	11	0.01
Hip fracture	89	94	87	80	59	51	0.00
Fracture upper extremities	16	16	22	27	20	17	0.82
Other fracture	31	27	29	33	28	29	0.31
Other injury	30	26	30	37	43	25	0.98
Location of injury (absolute number)							
In and around home	9,458	10,018	11,800	16,404	20,639	22,745	n.a.
In a nursing home	2,684	2,751	2,694	3,324	3,368	3,250	n.a.
On the street	1,172	1,155	1,366	2,185	2,367	2,611	n.a.
Other location	10,414	11,729	14,420	16,434	14,088	11,406	n.a.
Location of injury (standardized incidence rate per 10,000 population)							
In and around home	69	66	70	84	84	76	0.33
In a nursing home	20	19	16	17	14	11	0.00
On the street	8	7	8	11	10	9	0.75
Other location	75	77	85	84	58	38	0.00

yr, years; *, annual change over time of standardized incidence rates; a p-value <0.05 is considered statistically significant.

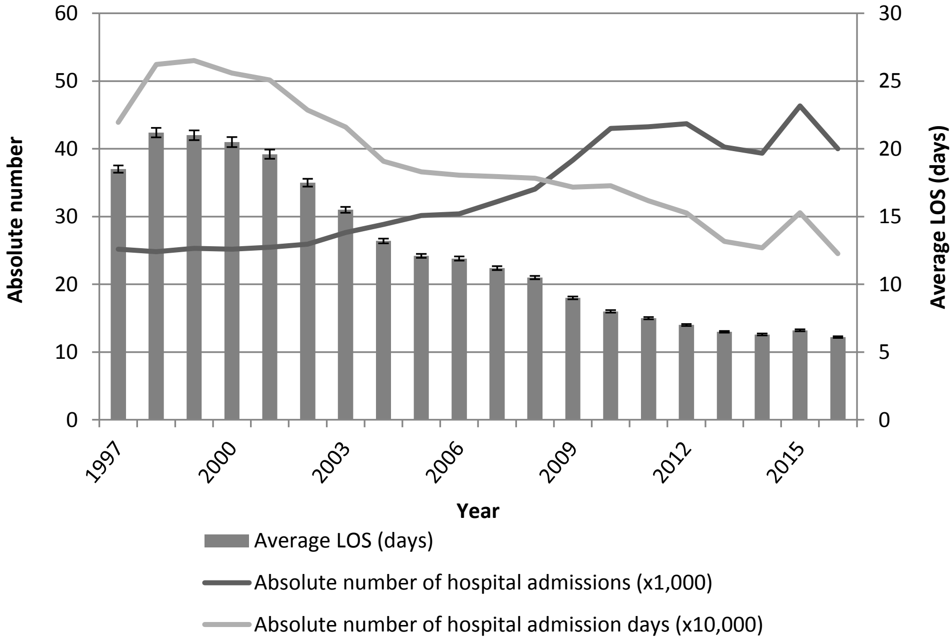

Figure 2. Absolute number of hospital admissions, hospital admission days, and average length of hospital stay (LOS) among adults aged ≥65 years in the Netherlands, 1997-2016.

3.3 Fall-related mortality

Fall-related mortality showed an almost threefold increase, from 1361 cases in 1997 to 3644 cases in 2016 (Fig. 1c). The number of fatalities increased by age. There was no significant overall change in the standardized mortality rates throughout the years, irrespective of age groups (Table 3).

Table 3. Absolute number and standardized incidence rates of fall-related mortality among adults aged ≥65 years in the Netherlands, 1997-2016.

	1997	2001	2005	2009	2013	2016	p-value*
Absolute number of fatalities							
≥65 yr	1,361	1,842	1,743	1,979	2,651	3,644	n.a.
65-74 yr	124	159	171	208	208	320	n.a.
75-84 yr	462	606	603	608	768	1,033	n.a.
≥85 yr	775	1,077	969	1,163	1,675	2,291	n.a.
Standardized incidence rate per 100,000 population							
≥65 yr	109	131	109	103	107	121	0.73
65-74 yr	15	19	19	21	15	19	0.44
75-84 yr	103	89	90	83	97	98	0.78
≥85 yr	671	780	630	554	593	667	0.49

yr, years; *, percentage annual change over time of standardized incidence rates; a p-value <0.05 is considered statistically significant.

3

4. Discussion

The current study shows time trends of fall-related healthcare use and mortality among older adults (≥65 years) in the Netherlands between 1997 and 2016. Although the standardized incidence rate of ED visits decreased by 30% (p=0.00), and the incidence rates of hospital admissions and mortality did not significantly change during the study period, the absolute number of fall-related ED visits, hospital admissions, and fatalities largely increased. This was accompanied by a shift in the fall-related injury diagnosis pattern with a growing share of skull/brain injuries due to increased standardized incidence rates for this injury type. In spite of the growing number of fall-related hospital admissions, the absolute number of hospital admissions days has almost halved in the same period, due to a reduction in the average LOS over time. Similar to our study, an Australian study reported a non-significant change in standardized incidence rates of hospital admissions between 1998 and 2009 [2]. A previous study performed in the Netherlands reported that the absolute number of hospital admission days decreased considerably, between 1981 and 2008 [5]. Our study showed that from 2008 to 2016, the number of admission days kept decreasing, which can be explained by a reduction in the average LOS over time. A study performed in the United States reported a 27% (2.2 to 2.8 million) increase of fall-related ED visits, from 2003 to 2010 [9]. Similarly, in the same period, an increase of 25% (48% from 1997 to 2016) was reported in our study. However, our study observed that, between 2003 and 2010, standardized incidence rates of ED visits decreased among all age groups, whereas the study performed in the United States observed increases in standardized incidence rates among adults aged 75–84 years, whereas the incidence rates among the other ages group (65–74 years and≥85 years) did not change over time [9]. A significant (31%, from 47.0 to 61.6 per 100,000) increase of standardized mortality rates was observed in the United Sates between 2007 and 2016 [1], whereas our study did not observe a significant change during that time. A study performed in Spain reported an even higher increase of standardized mortality rates per 10,000 person-years of 51% (16.3 to 24.6 per 100,000 person years), between 2000 and 2015 [8]. However, studies performed in Finland showed that standardized mortality rates increased between 1971 and 1998, after which rates steadily declined from 1998 (in women) and 2005 (in men) onwards [6, 21]. These differences could be explained by the fact that healthcare systems and population numbers differ between countries. Increases in absolute numbers of fall-related ED visits, hospital admissions, and mortality can be partly explained by an ageing population. As reported in the methods section, between 1997 and 2016, the Dutch population aged ≥65 years increased by 147%. The ageing population could also be an explanation for changes in the location of a fall over time. The current study showed that absolute numbers of falls in and around the house have increased from 1997 to 2016, whereas falls on the street decreased. As the oldest old have a restricted living area and spend much time at home, they could be more likely to fall in and around the house. Another explanation for changes in the location of a fall could be that, over time, more older adults are living independently at home in the Netherlands (2.1 million in 1997, 3.1 million in 2016), whereas less older adults are living in a residential care facility (160.000 in 1997, 130.000 in 2016) [18]. Decreases in standardized incidence rates of fall-related ED visits could be explained by a healthier, more active population of older adults. It is possible that fall-related injuries are more often treated at the general practitioner, outside of a hospital, or the injuries are treated at general practice centres which are more often located near EDs. An improvement in healthcare services and better techniques (e.g. hip replacement surgery) could have resulted in the observed reduction of hospital admission days. Furthermore, changes in hospital discharge policy over the years have been made in order to lower healthcare costs, which is assumed to have reduced the length of stay, as well. A change in hospital discharge policy could also have resulted in the decrease in the variation in hospital admission days, as the 95% CIs reduced from 18.2 to 18.8 days in 1997 to 6.1–6.2 days in 2016. Although standardized ED visit rates have decreased in the past twenty years, standardized incidence rates of fall-related skull/brain injuries did increase. Earlier studies have also found that traumatic brain injuries increased in the past decade, which was mainly driven by falls among older adults [22, 23]. The ageing population and the increased use of computed tomography imaging could be an explanation for these increases [23]. We found that the absolute number of fall-related hospital admissions due to hip fractures has increased between 1997 and 2016, but standardized incidence rates decreased significantly from 89 to 51 per 10,000. A study performed in Finland showed a similar trend in a nationwide analysis on hip fractures. After an increase in standardized incidence rates from 1970 onwards, a decline was reported from 1997 until 2016 [24]. Possible explanations for this decrease are, among others, the improved prevention and treatment of osteoporosis, and the existence of effective falls prevention interventions [24]. A strength of our study is the use of reliable and valid data on sex, different age groups, diagnosis, and location of injury, with a high national coverage, over a period of twenty years. A limitation is that the results are based on one country. Results may differ in other countries due to differences in healthcare systems and population numbers. Nonetheless, data on fall-related injuries of the Netherlands are comparable to data of other western societies, based on e.g. definition and classification of falls [25]. Furthermore, changes in data sources and coding of fall-related injuries and mortality could have occurred during the past two decades. This might have caused slight differences in incidence rates. Also, apart from the ICD-10, W00-W19, and X59 codes, no use has been made of chief complaint codes to identify fall-related injury. This could have resulted in an underestimation of true numbers [26]. However, data was very reliable as it was collected with a uniform classification system and it was extrapolated from a representative sample [13-17]. Future internationally comparative research is required in order to explore whether the time trends in fall-related healthcare use and mortality data are comparable with other populations.

5. Conclusion

Despite a decrease in standardized incidence rates of fall-related ED visits in the past twenty years, the absolute numbers of fall-related ED visits increased, leading to an increased workload on EDs. The number of hospital admissions has also increased, but the total number of admission days has almost halved during the same period, due to a reduction in the average LOS per patient. If this trend would continue in the coming years, this may have implications for healthcare resource allocation, as the burden of care in EDs increases, and the admission duration reduces. Our study shows a promising reduction in standardized incidence rates of ED visits, and in hospital admission days, but it remains important to implement effective falls prevention programs in society in order to deal with the increasing absolute burden of fall-related healthcare use and mortality.

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7. Supplementary material

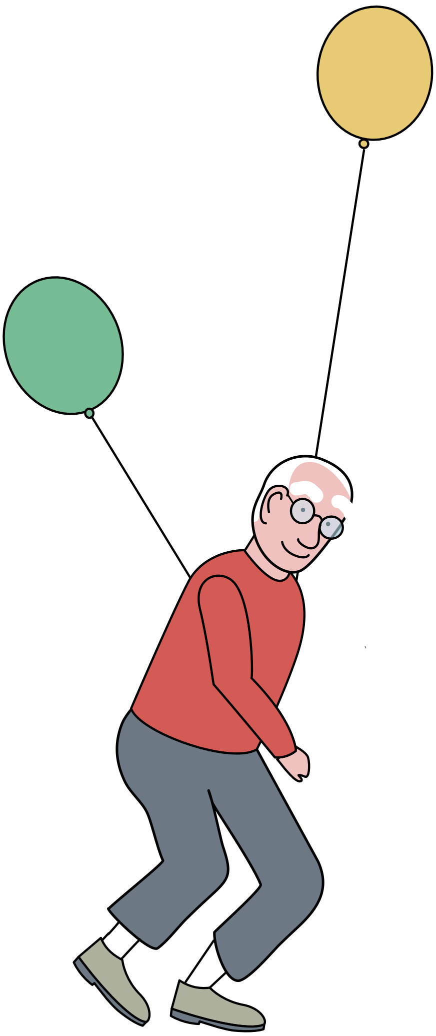
Supplementary Text S1. Calculation of extrapolation factors of fall-related Emergency Department visits and fall-related hospital admissions among adults aged ≥65 years in the Netherlands, 1997-2016.

By using a representative sample of Emergency Departments (EDs) of the Dutch Injury Surveillance System (DISS), it was possible to extrapolate the recorded unintentional injury cases to national estimates. An extrapolation factor was calculated as follows:

$$\frac{\text{n ED visits sample} * \text{n hospital admissions all hospitals}}{\text{n hospital admissions sample}}$$

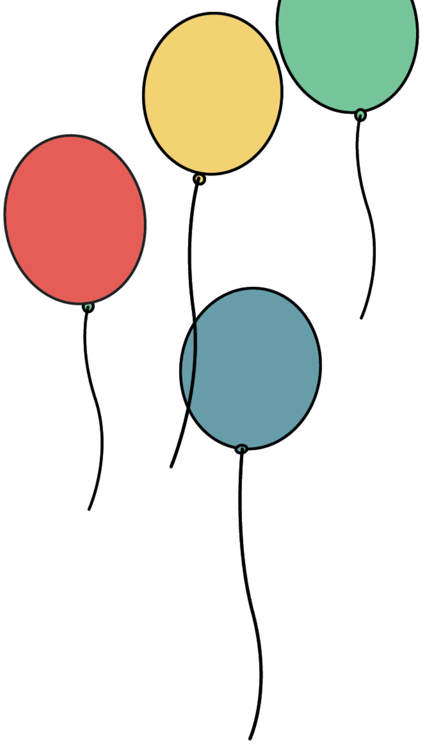
The Dutch Hospital Discharge Registry (HDR), which collects hospital data of all hospitals in the Netherlands with a uniform classification system and a high national coverage (missing values <10%), was used in order to extrapolate the data to full national coverage for each year, by calculating an extrapolation factor as follows:

$$\frac{\text{n total Dutch population}}{\text{n hospital admissions sample}}$$



PART II

Cost-effectiveness of falls prevention



CHAPTER 4

Economic evaluations of falls prevention programs for older adults: A systematic review

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Abstract

Objectives: To provide a comprehensive overview of economic evaluations of falls prevention programs and to evaluate the methodology and quality of these studies.
Design: A systematic review of economic evaluations on falls prevention programs.
Setting: Studies (n=31) on community-dwelling older adults (n=25), on older adults living in residential care facilities (n=3), or on both populations (n=3), published before May 2017, were included.
Measurements: Information on study characteristics and health-economics was collected. Study quality was appraised using the 20-item Consensus on Health Economic Criteria.
Results: Economic evaluations of falls prevention through exercise (n=9), home assessment (n=6), medication adjustment (n=4), multifactorial programs (n=11), and various other programs (n=13) were identified. Approximately two-thirds of all reported incremental cost-effectiveness ratios (ICERs) with quality adjusted life-years (QALYs) as outcome were below the willingness-to-pay threshold of \$50,000 per QALY. All studies on home assessment and medication adjustment programs reported favourable ICERs, whereas the results of studies on exercise and multifactorial programs were inconsistent. The overall methodological quality of the studies was good, although there was variation between studies.
Conclusion: The majority of the reported ICERs indicated that falls prevention programs were cost-effective, but methodological differences between studies hampered direct comparison of the cost-effectiveness of program types. The results imply that investing in falls prevention programs for older adults aged 60 years and older is cost-effective. Home assessment programs (ICERs <\$40,000 per QALY) were the most cost-effective type of program for community-dwelling older adults and medication adjustment programs (ICERs <\$13,000 per QALY) were the most cost-effective type of program for older adults living in a residential care facility.

1. Introduction

Fall-related injuries have a large impact on global health in older adults [1]. Furthermore, consequences of fall-related injuries are associated with increased costs for medical consultation and treatment [2]. The mean healthcare costs for an injurious fall treated at the emergency department are $11,450, and this amount increases with age [3]. Almost two-thirds of all fall-related healthcare costs can be attributed to hospital and nursing home admissions [3]. Studies have shown that exercise programs and programs combining multiple components, such as exercise and home assessment, effectively reduce fall-related injuries in older adults [4-7]. Although effective falls prevention programs exist, the occurrence of falls among older adults is still high. Because financial resources in healthcare are limited, it is important that policy-makers invest in the implementation of cost-effective falls prevention programs. An up-to-date overview of all published economic evaluations of falls prevention programs and their methodological quality is relevant as the results can inform policy decisions. Previous systematic reviews of economic evaluations of falls prevention programs have shown that programs consisting of home visits [8], and those consisting of strength and balance exercises [9] are cost-effective. Davis et al. (2010) published a comprehensive overview of economic evaluations of falls prevention programs, which was limited to community-dwelling older adults [9]. Since that publication, 22 new economic evaluations of falls prevention programs have been published. Therefore, an update is deemed relevant. The aim of this review is to provide a comprehensive overview of economic evaluation studies on falls prevention programs among community-dwelling older adults and older adults living in a residential care facility, and to evaluate the study designs, health-economic characteristics, outcomes, and methodological quality of these studies. This review is focused on a broader population and it makes a distinction between community-dwelling older adults and older adults living in a residential care facility. Furthermore, the results are compared with common WTP thresholds, as this is the next step in an informed decision-making process.

2. Materials and methods

The methods and reporting of this systematic review are in concordance with the PRISMA statement [10]. The study protocol is registered in the PROSPERO register (number CRD42017071726).

2.1 Literature search

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

2.2 Study selection

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

2.3 Data extraction

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

2.4 Outcome

The primary outcome measure was the incremental cost-effectiveness ratio (ICER). An ICER is a standard outcome in economic evaluations and is expressed as the additional costs per unit of outcome gained for the intervention compared to usual care. The outcome as defined in the individual studies is reported. In case an ICER was not reported, but a full economic evaluation was performed, the health-economic results were reported descriptively. In order to compare price levels between countries, all ICERs were converted to 2016 US$ by using purchasing power parity rates and the Consumer Price Index [12, 13]. In order to maintain comparability of the results of the included CUAs with QALY as outcome, a willingness-to-pay (WTP) threshold of US$ 50,000 per QALY gained was applied, which is a widely accepted threshold in the US [14]. Because the threshold of $50,000 has been in use since the 1980s, we have used this as a lower boundary, and the outcomes were compared with a commonly used inflation-adjusted threshold of $100,000 per QALY [15]. The WTP threshold is the maximum amount society is willing to pay for gaining one additional QALY. When the ICER is lower than the threshold, the program is considered cost-effective in comparison with the control condition. The ICERs of CEAs were not compared with a threshold, as generally accepted thresholds do not exist for outcomes other than QALYs.

2.5 Quality assessment

In concordance with the Cochrane collaboration guidelines [16], the quality of the studies was assessed with the extended Consensus on Health Economic Criteria (CHEC) [17]. The CHEC contains 20 items covering internal and external validity of economic evaluation studies (Supplementary Text S2). Each item on the CHEC checklist was scored with ‘No’ (0), ‘Suboptimal’ (0.5), ‘Yes’ (1), or ‘NA’, as described by Ophuis et al. [18]. The sum score (%) for each study was reported in this review. The quality of the studies was assessed and scored independently by two reviewers (BO and RO). A third reviewer (SP) was involved for resolving discrepancies. The correlation between the total quality scores and ICERs are expressed in a Pearson's correlation coefficient, Separate correlation coefficients were calculated for CUAs, CEAs, falls prevention program type, and population. The critical p-value was set at 0.05.

3. Results

3.1 Literature search and study selection

The literature search yielded 5,209 studies. After removing duplicates, the titles and abstracts of 3,063 studies were screened for relevance. This resulted in the exclusion of 2,980 studies for the following reasons: not primarily focused on falls prevention programs, and no economic evaluation. Eighty-three studies were read in full-text for eligibility assessment. Fifty-four studies were excluded for the following reasons: no full economic evaluation (n=32), no original research (n=11), population aged under 60 years (n=6), and protocol article (n=5). Two additional studies were identified through scanning the reference lists of included studies included. Thirty-one studies were included in the systematic review (Figure 1). The studies included were published between 1996 and 2017. The study populations were community-dwelling older adults (n=25), older adults living in a residential care facility (n=3), or both populations (n=3). The following falls prevention programs were identified: exercise (n=9), home assessment (n=6), medication adjustment (n=4), multifactorial programs (n=11), and other programs (n=13). The content of the multifactorial programs can be found in Supplementary Text S3. Most of the studies compared falls prevention programs with usual care or no program. The number of falls prevented and QALYs were mainly used as outcome. The study characteristics are reported in Supplementary Table S1.

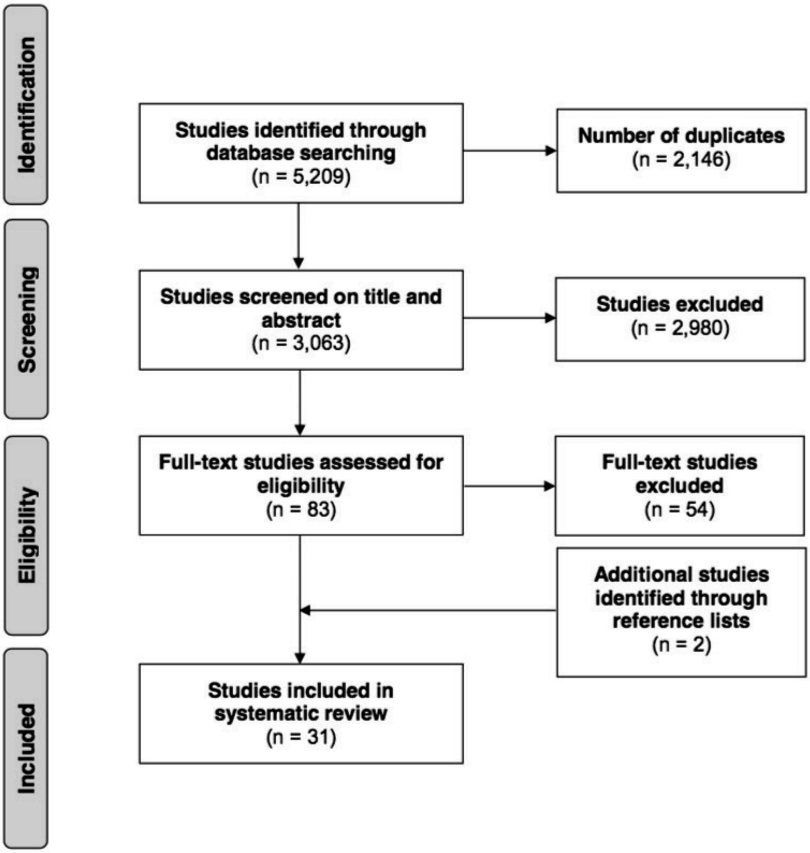

Figure 1. Flowchart of search for studies of cost-effectiveness of falls prevention programs for older adults.

3.2 Quality assessment

Quality scores ranged from 62% to 97% (Table 1, Supplementary Table S2). The average score of 84% shows that the overall methodological quality was good. The quality of the studies on home assessment and medication adjustment programs had the lowest scores on average (82%); whereas exercise and other programs had the highest scores (88%). The studies reporting a cost saving or cost-effective falls prevention program had an average score of 83%. Studies that did not report a cost saving or cost-effective program scored 91% on average. There was no significant correlation between the quality score and the reported ICERs for CUAs ($r(44)=-0.04$, $p=0.808$) and CEAs ($r(44)=-.14$, $p=0.366$). The association remained non-significant when the correlation analysis was performed for program type and population.

Table 1. CHEC quality assessment items and scores, subdivided by falls prevention program.

Authors, year	**Quality score (%)**[a]
Exercise programs	
Church et al. 2011	83
Church et al. 2012	83
Davis et al. 2011	89
Farag et al. 2015	92
McLean et al. 2015	95
Munro et al. 2004	72
Robertson et al. 2001 (1)	94
Robertson et al. 2001 (2)	91
Robertson et al. 2001 (3)	91
Average	88
Home assessment programs	
Campbell et al. 2005	78
Church et al. 2012	83
Pega et al. 2016	83
Sahlen et al. 2008	84
Salkeld et al. 2000	85
Smith et al. 1998	76
Average	82
Medication adjustment programs	
Church et al. 2011	83
Church et al. 2012	83
Church et al. 2015	93
Frick et al. 2010	68
Average	82
Multifactorial programs	
Church et al. 2011	83
Church et al. 2012	83
Church et al. 2015	93
Farag et al. 2014	75
Heinrich et al. 2013	86
Hendriks et al. 2008	89
Irvine et al. 2010	92
Jenkyn et al. 2012	79
Müller et al. 2014	83
Peeters et al. 2011	92
Rizzo et al. 1996	62
Average	83
Other programs	
Church et al. 2011	83
Church et al. 2012	83

Table 1. Continued.

Authors, year	Quality score (%)[a]
Church et al. 2015	93
Lee et al. 2013	90
Patil et al. 2016	97
Poole et al. 2015	75
Sach et al. 2007	89
Cockanye et al. 2017	63
Mori et al. 2017	93
Van Haastregt et al. 2013	94
Average	86

[a] Score expressed as percentage of the maximum score.

3.3 Economic evaluations

Nineteen studies performed a CUA with QALYs as outcome. In the majority of these studies, QALYs were calculated by multiplying utility values by the remaining life years corresponding to the time horizon of the studies. Thirteen studies used utility values that were derived from the EQ-5D. One study used the SF-36, and one study used the EQ-5D and SF-36. Three studies did not report how utility values were derived. A societal perspective (n=13) was applied as often as a healthcare perspective (n=13) (Supplementary Table S3). All studies with a healthcare perspective included program costs and other healthcare costs in their analyses (Supplementary Table S4 and S5). Nineteen trial-based economic evaluations (TBEEs) and twelve model-based economic evaluations (MBEEs) were identified. The most commonly applied time horizon among TBEEs was one year (58%), followed by two years (11%). Among the MBEEs, the most commonly applied time horizon was a lifetime horizon (50%). Ten TBEEs (53%) applied bootstrapping in order to deal with sampling uncertainty. The main cost-effectiveness findings of this review were subdivided by program type (Supplementary Table S3). Figure 2 provides a graphical overview of all reported ICERs in the CUAs, subdivided by program type. In this figure, a distinction was made between community-dwelling older adults and older adults living in a residential care facility. In total, about two-thirds of the ICERs with QALYs as outcome were below the WTP threshold of $50,000 per QALY (Figure 2), and 86% of the ICERs were below the threshold of $100,000 per QALY. All ICERs of home assessment and medication adjustment programs were cost-effective given both thresholds. Half of the reported ICERs of exercise programs and multifactorial programs and over two-thirds of the reported ICERs of various other programs indicated that these programs were cost-effective when a threshold of $50,000 per QALY is applied. However, all ICERs of exercise programs and the vast majority of the ICERs of multifactorial programs were below the threshold of $100,000 per QALY. Figure 3 presents all reported ICERs with falls as outcome. The majority of the ICERs of exercise programs, and all ICERs of medication adjustment programs were below $2,000 per fall prevented (Figure 3). In contrast, most of the ICERs of multifactorial programs were higher than $2,000 per fall prevented.

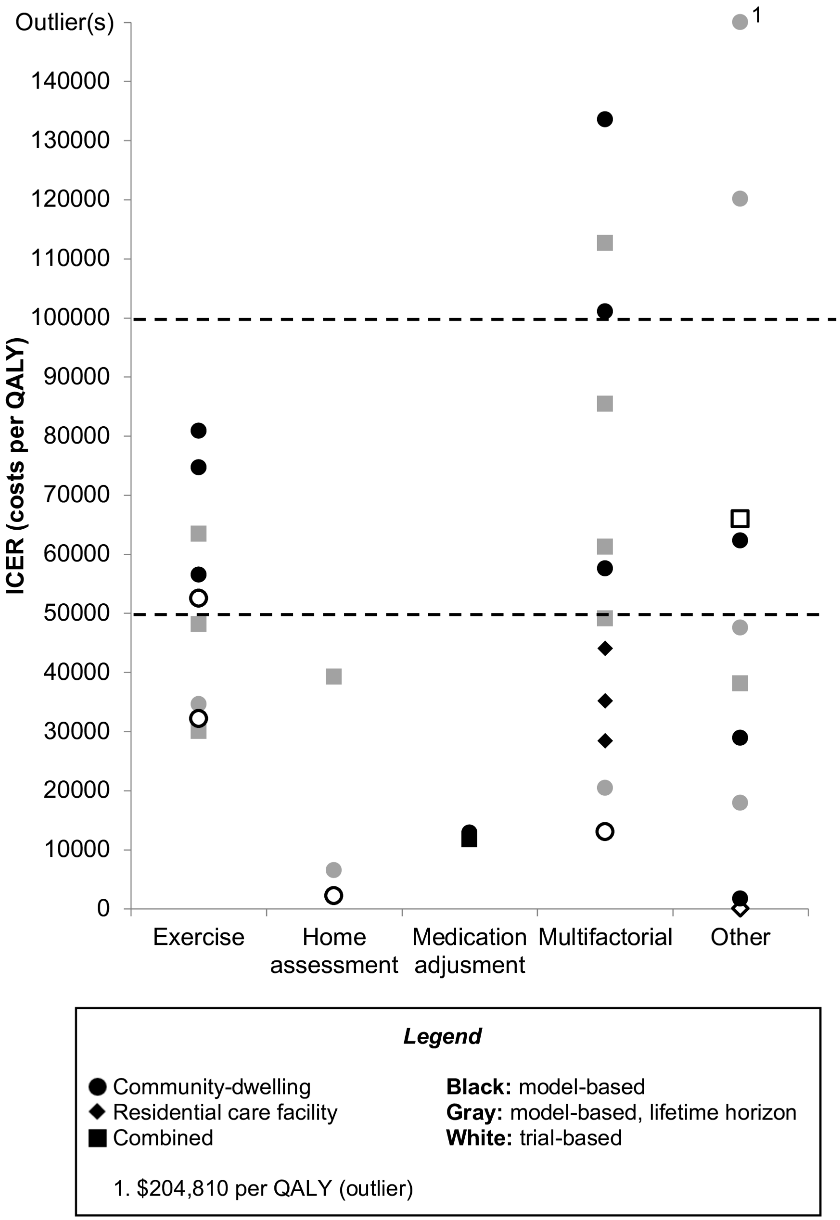

Figure 2. Overview of incremental cost-effectiveness ratios (ICERs) per falls prevention program, with costs per quality-adjusted life year (QALY) gained as outcome (cost-saving ICERS excluded).

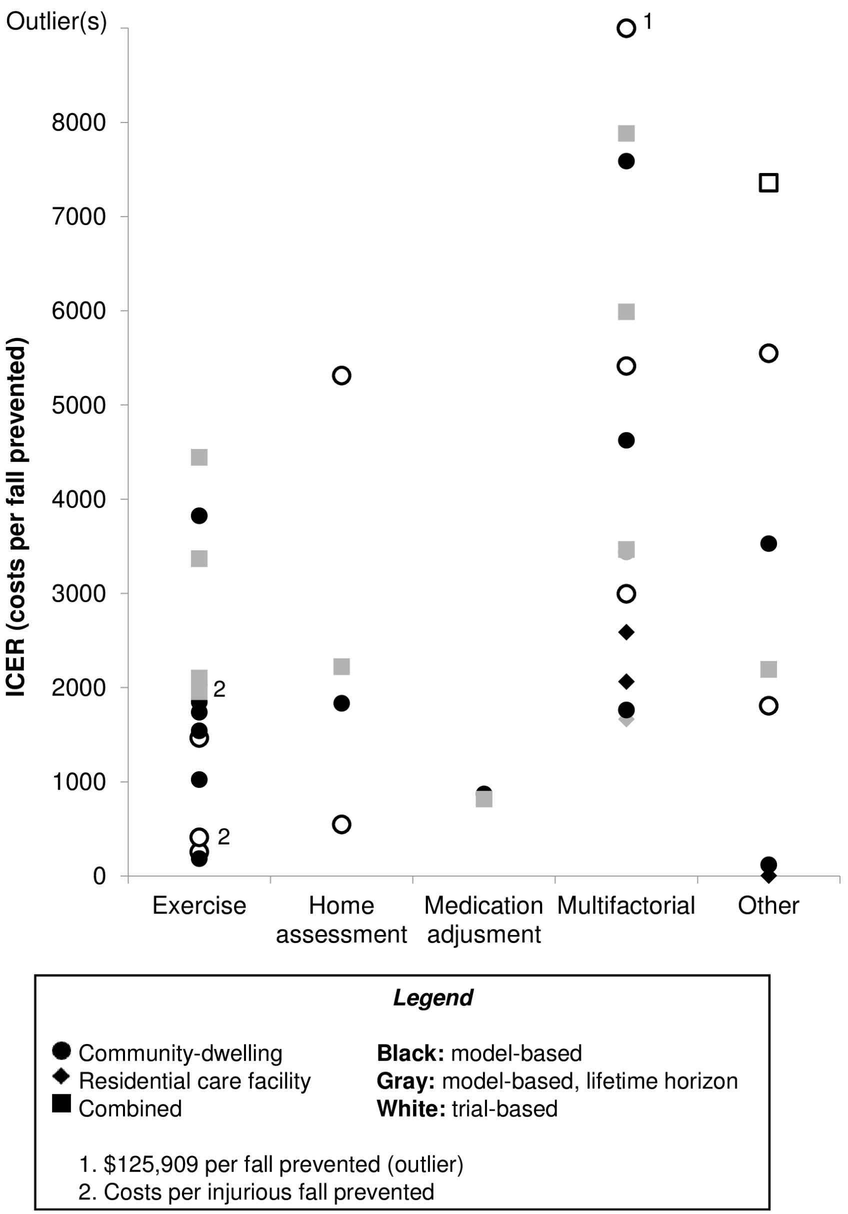

Figure 3. Overview of incremental cost-effectiveness ratios (ICERs) per falls prevention program, with costs per fall prevented as outcome (cost-saving ICERS excluded).

3.3.1 Exercise programs

Nine economic evaluations of exercise programs were identified [19-27]. The ICERs of CUAs ranged from $30,013 to $80,860 per QALY. Six ICERs of CUAs were cost-effective based on a threshold of $50,000 per QALY and of $100,000 per QALY. Davis et al. (2011) reported that once-weekly resistance training and twice-weekly resistance training were cost saving in comparison with twice-weekly balance and tone classes [21]. The ICERs of CEAs on exercise programs ranged from $186 to $4,446 per (injurious) fall prevented. Robertson et al. (2001) reported relatively low ICERs of CEAs for older populations (≥75) [25-27]. Church et al. (2011, 2012) showed that Tai Chi and group-based exercise in a high-risk population were the most cost-effective programs [19, 20].

3.3.2 Home assessment programs

Economic evaluations of home assessment programs were performed in six studies [20, 28-32]. The ICERs of CUAs ranged from $2,158 to $39,281 per QALY and were all below thresholds of $50,000 and $100,000 per QALY. The ICERs of CEAs ranged from $548 to $5,313 per fall prevented. The studies with an older population (≥75) reported lower ICERs than the studies with a younger population (≥65).

3.3.3 Medication adjustment programs

Four economic evaluations of medication adjustment programs were identified [19, 20, 33, 34]. Church et al. (2011,2015) reported the ICERs of CUAs on medication review or withdrawal and showed that it was cost saving in a population of older adults living in a residential care facility [19, 33]. Furthermore, Church et al. (2012) showed that the program was cost-effective in community-dwelling older adults [20]. Frick et al. (2010) compared the ICERs of CUAs of a medication adjustment program with exercise, home assessment, multifactorial, and vitamin D programs and reported that medication adjustment was the least expensive and most effective program in community-dwelling older adults [34]. The studies by Church et al. also showed relatively low or cost saving ICERs of CEAs on a medication review and withdrawal program [19, 20, 33].

3.3.4 Multifactorial programs

Eleven studies performed an economic evaluation of multifactorial programs [19, 20, 33, 35-42]. The ICERs of CUAs ranged from $20,427 to $112,598 per QALY. Seven out of fourteen ICERs were below the threshold of $50,000 per QALY, and ten were below $100,000 per QALY. Two studies reported that their program in community-dwelling older adults (≥65) was less effective and costlier than the control condition [37, 41]. The ICERs of CEAs ranged from $1,666 to $125,909 per fall prevented. The ICERs were lower in a population living in a residential care facility than in a community-dwelling population. Furthermore, in both populations, a program consisting of the modification of risk factors, information sessions, and follow-up had the lowest ICERs.

3.3.5 Other programs

Economic evaluations of a variety of other falls prevention programs (vitamin D, cataract surgery, cardiac pacing, podiatry care, bisphosphonates and exercise, and cognitive behavioural therapy) were reported in thirteen studies [19, 20, 33, 43-49]. Eleven ICERs of CUAs were reported in these studies, of which seven programs were cost saving or cost-effective [19, 20, 33, 43, 47]. However, nine were cost-effective given a threshold of $100,000 per QALY. Mori et al. (2017) showed that with an increase in age, the costs per QALY decreases [45]. Additional information on the other programs can be found in Supplementary Table S3.

4. Discussion

This systematic review provides a comprehensive overview of the results of 31 economic evaluations on falls prevention programs among community-dwelling older adults and older adults living in a residential care facility. In general, medication adjustment programs and home assessment programs showed the most favourable results because the lowest ICERs were reported for these program types. However, when a higher WTP threshold of $100,000 is applied, the majority of the remaining program types (exercise, multifactorial, and other) were also cost-effective. Given the earlier published review by Davis et al. (2010) [2], it appears that medication adjustment programs and vitamin D supplementation and cataract surgery are also falls prevention programs that are potentially cost saving. Direct comparison of the relative cost-effectiveness between program types was hampered by the methodological differences between the studies. The majority of the TBEEs were powered for falls and not for costs. This may have contributed to the heterogeneity of the results, as costs often have a very skewed distribution [9]. It should be noted that these findings are mainly based on CUAs because there is no generally accepted cost-effectiveness threshold for the costs per fall prevented. This review shows that home assessment programs were the most cost-effective type of program for community-dwelling older adults. Medication adjustment programs were the most cost-effective type of program for older adults living in a residential care facility. The results for mixed populations were more inconsistent, but for higher WTP thresholds exercise, home assessments, and medication adjustment programs were all cost-effective. In general, multifactorial programs and other programs were less favourable, but it should be noted that these programs were more frequently assessed than home assessment and medication adjustment programs. Namely, multifactorial programs were assessed eleven times and other programs were assessed thirteen times; whereas, when combining home assessment and medication adjustment programs, ten assessments were made. This could have contributed to a wider range of results. A possible explanation for the less favourable cost-effectiveness results for exercise and multifactorial programs is that the program costs for these programs are likely to be higher than the program costs for home assessment and medication review programs. Home assessment and medication review programs are often one-time only programs, whereas exercise and multifactorial programs consist of multiple classes or appointments. A difference in health-economic perspective or baseline fall risk between studies could have contributed to differences in cost-effectiveness results as well. The cost-effectiveness of interventions depends on the WTP threshold. For this study WTP thresholds of $50,000 and $100,000 for one QALY gained were applied, but WTP values in general have no solid scientific basis [50]. Choosing a relevant WTP threshold is essential for policy-making, as the inappropriate use of WTP thresholds might lead to inappropriate decisions. For example, the cost-effectiveness of falls prevention programs severely decreases when a lower threshold of $20,000 per QALY is applied. In this case, the majority of the ICERs reported are above the threshold. Conversely, the cost-effectiveness increased substantially when a higher threshold of $100,000 was applied. Studies performed on older adults living in a residential care facility reported slightly more favourable ICERs than studies performed on community-dwelling older adults. However, it is not warranted to conclude that falls prevention programs are more cost-effective among adults living in a residential care facility, as only three studies were performed in these populations. Additional research is needed in order to properly compare the results for different populations in economic evaluations of falls prevention programs. Studies on older populations reported more favourable ICERs than studies on younger populations. However, 90% of the ICERs of CUAs originated from studies on older adults aged 65 to 75 years old whereas 10% of the ICERs originated from studies on older adults over the age of 75 years. Therefore, one is unable to draw firm conclusions about age differences. A possible explanation for the observed differences between age groups is that older people are more likely to fall [51]. More falls can thus be prevented as a result of a prevention program. Older people are also more often hospitalized after fall-related injury, which is associated with high healthcare costs [51]. Consequently, more costs could be saved among older people. Relevant study quality differences between falls prevention program types could not be identified. On average, studies reporting a cost saving or cost-effective falls prevention program had lower quality scores than studies not describing a cost-effective falls prevention program (83% versus 91%), but the difference was small and therefore not likely to be influential. One of the strengths of this review is that standardized methods for conducting and reporting systematic reviews were followed. All reported ICERs were converted to 2016 US$ which allows for comparison between cost data. Differences resulting from purchasing power and inflation were eliminated. Another strength of this study is the extensive health-economic quality assessment. This review also has several limitations. Although WTP thresholds differ between countries, the same two WTP thresholds were applied for all CUAs. Selection bias might be present because the search was limited to English-language papers that were published in peer-reviewed scientific journals. In determining the overall cost-effectiveness of home assessment and medication adjustment programs, the effectiveness of these programs has to be taken into account as well. Reviews have shown that the evidence on the effectiveness of these programs is fairly inconsistent [4, 6]. Publication bias in economic evaluations is likely to be present, as economic evaluations are less likely to be performed when an intervention is ineffective [52]. Therefore, the findings presented in this review are likely to overestimate the cost-effectiveness of falls prevention programs in general. Future economic evaluations of falls prevention programs should be designed, conducted, and reported in accordance with the current guidelines for economic evaluations in order to increase comparability, which is essential for informing decision-making [53, 54]. In addition, comprehensive cost-effectiveness models comparing multiple falls prevention programs such as described by Church et al., provide insight into the relative cost-effectiveness of different program types within the same population [19, 20, 33]. Furthermore, QALYs are preferred as outcome in addition to clinical effect measures as QALYs can be compared with established WTP thresholds. Comparing the QALYs in this review with two WTP thresholds shows that the majority of falls prevention programs are cost-effective. Moreover, some studies show that falls prevention is effective while costs can be saved. Thus, decision makers should consider implementing falls prevention programs, also taking the increasing impact of fall-related injuries among older adults into account. Future studies should clearly report whether they target high-risk, low-risk, or mixed populations as the baseline fall-risk is an important driver for cost-effectiveness [2]. This is important for identifying whether falls prevention programs are more cost-effective for certain risk groups because some studies reported more favourable results for older adults with a higher fall risk. This review implies that investing in falls prevention programs for adults aged 60 years and older is cost-effective, which particularly applies to home assessment for community-dwelling older adults and medication adjustment programs for older adults living in residential care facilities. Moreover, programs are found to be more cost-effective as the age of participants increases.

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6. Supplementary material

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

Authors, year	Country	Population (n)	Program(s)	Comparator	Effect measurement and valuation[a]
Community-dwelling					
Campbell et al. 2005	New Zealand	Men and women aged ≥75 years, severe visual impairment (391)	Home safety and modification program	No program	Number of falls
Cockanye et al. 2017	UK and Ireland	Men and women aged ≥65 years, from podiatry clinics (1,010)	Multifaceted podiatry care	Routine podiatry care	Number of falls, QALYs (utility EQ-5D)
Davis et al. 2011	Canada	Women aged 65-75 years (155)	Once-weekly resistance training and twice-weekly resistance training	Twice-weekly balance and tone classes	Number of falls, QALYs (utility EQ-5D & SF-36)
Farag et al. 2014	Australia	Men and women aged ≥65 years (NR)	Public health program	No program	QALYs (utility valuation NR)
Farag et al. 2015	Australia	Men and women aged ≥60 years, recent hospital admission (340)	Home-based exercise program	Usual care	Mobility, self-rated health status, QALYs (utility EQ-5D)
Frick et al. 2010	USA	Older adults (age unknown) (NR)	7 programs[b]	Usual care	QALYs (utility valuation NR)
Hendriks et al. 2008	The Netherlands	Men and women aged ≥65 years, visited ED or GP after a fall (249)	Multidisciplinary program	Usual care	Number of falls (base case), QALYs (utility EQ-5D)
Irvine et al. 2010	UK	Men and women aged ≥70 years, identified as high risk of falling (364)	Multifactorial program with leaflet	Leaflet only	Number of falls
Jenkyn et al. 2012	Canada	Men and women (mean age ± 80 years), veterans and caregivers (348)	Multifactorial risk factor modification	Usual care consisting of community based primary care	Number of falls
Lee et al. 2013	USA	Men and women aged 60-80 years (NR)	Screening for vitamin D	Universal vitamin D supplementation	QALYs (utility valuation NR)

Supplementary Table S1. Continued.

Authors, year	Country	Population (n)	Program(s)	Comparator	Effect measurement and valuation[a]
McLean et al. 2015	Australia	Men and women aged ≥70 years (1,090)	Group-based exercise program	Routine care for falls prevention	Number of (injurious) falls, QALYs (utility EQ-5D)
Mori et al. 2017	USA	Women aged ≥65 years, non-Hispanic white (NR)	Bisphosphonates and exercise (Otago)	Bisphosphonates only	QALYs (utility EQ-5D)
Munro et al. 2004	UK	Men and women aged ≥65 years (6,420)	Community based exercise program	Control	QALYs (utility SF-36)
Patil et al. 2016	Finland	Women aged 70-80 years (307)	Vitamin D supplementation and exercise	Placebo and no exercise	Number of injurious falls
Peeters et al. 2011	The Netherlands	Men and women aged ≥65 years, at high risk of falling (217)	Multifactorial evaluation	Usual care	Number of falls and recurrent falls, QALYs (utility EQ-5D)
Pega et al. 2016	New Zealand	Men and women aged ≥65 years (NR)	Home safety assessment and modification	Usual care	QALYs (utility valuation NR)
Poole et al. 2015	UK	Men and women aged ≥60 years (NR)	Vitamin D supplementation	Current care	QALYs (utility EQ-5D)
Rizzo et al. 1996	USA	Men and women aged ≥70 years, at risk for falling (301)	Medication adjustment, behavioural recommendations, and exercises	Usual care consisting of home visits by a social work student	Number of falls
Robertson et al. 2001 (1)	New Zealand	Women aged ≥80 years (233)	Home based muscle strengthening and balance retraining program (Otago)[c]	Usual care and social visits	Number of (injurious) falls
Robertson et al. 2001 (2)	New Zealand	Men and women aged ≥75 years (140)	Home based exercise programd	Usual care	Number of (injurious) falls
Robertson et al. 2001 (3)	New Zealand	Men and women aged ≥80 years (450)	Home exercise program[d]	Usual care	Number of (injurious) falls
Sahlen et al. 2008	Sweden	Men and women aged ≥75 years (542)	Preventive home visits	Control	QALYs (utility EQ-5D)
Salkeld et al. 2000	Australia	Men and women aged ≥65 years (530)	Routine occupational therapy home assessment	Routine care	Number of falls

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Supplementary Table S1. Continued.

Authors, year	Country	Population (n)	Program(s)	Comparator	Effect measurement and valuation[a]
Smith et al. 1998	Australia	Men and women aged ≥75 years (NR)	Assessment of home hazards and provision of fall-prevention devices	No program	Number of falls and injuries
Van Haastregt et al. 2013	The Netherlands	Men and women aged ≥70 years, reporting fear of falling and fear-induced avoidance (540)	Multicomponent cognitive behavioural group program	Usual care	Fear of falling, activity avoidance
Older adults living in a residential care facility					
Church et al. 2015	Australia	Older adults (mean age ± 84 years) (NR)	Medication review, vitamin D supplementation, and multifactorial program	No program	Number of falls, QALYs (utility SF-36)
Heinrich et al. 2013	Germany	Men and women aged ≥65 years (33,152)	Multifactorial program	Control group	Femoral fractures
Müller et al. 2014	Germany	Men and women aged ≥80 years (NR)	Multifaceted program	No program	QALYs (utility EQ-5D)
Community-dwelling and older adults living in a residential care facility					
Church et al. 2011	Australia	Men and women aged ≥65 years (NR)	13 programs[e]	No program	Number of falls, QALYs (utility EQ-5D)
Church et al. 2012	Australia	Men and women aged ≥65 years (NR)	12 programs[f]	No program	Number of falls, QALYs (utility EQ-5D)
Sach et al. 2007	UK	Women aged ≥70 years, with bilateral cataracts (288)	Cataract surgery	Waitlist control	Number of falls, QALYs (utility EQ-5D)

ED: Emergency Department; EQ-5D: EuroQoL 5 dimensions questionnaire; GP: General practitioner; NR: Not reported; SF: short form questionnaire; QALY: quality-adjusted life year.

[a] Valuation method of utilities applicable only to cost-utility analyses.

[b] Tai Chi, Muscle balance training, Home modifications, Withdrawal of psychotropic medication, Vitamin D supplementation, Multifactorial (all older adults), Multifactorial (high-risk older adults).

c Individually prescribed by the research physiotherapist during four home visits.

[d] Delivered by trained nurse.

[e] Tai Chi, Group-based exercise, Home based exercise, Withdrawal of psychotropic medication (community-dwelling and residential care facility), Vitamin D supplementation, Cataract surgery, Cardiac pacing, Multiple program (community-dwelling and residential care facility), Multifactorial – active (community-dwelling and residential care facility), Multifactorial – referral.

[f] Group-based exercise (general and high risk population), Home based exercise, Tai Chi, Home hazard assessment and modification, Withdrawal of psychotropic medication, Cataract surgery, Cardiac pacing, Multiple program, Multifactorial – active, Multifactorial – referral, Multifactorial (high risk population).

Supplementary Table S2. CHEC quality assessment items and scores.

Item		Authors, year					
		Campbell et al. 2005	**Church et al. 2011**	**Church et al. 2012**	**Church et al. 2015**	**Cockanye et al. 2017**	**Davis et al. 2011**
1.	Is the study population clearly described?	1	1	1	1	1	1
2.	Are competing alternatives clearly described?	0.5	0.5	0.5	0.5	1	1
3.	Is a well-defined research question posed in answerable form?	1	1	1	1	0.5	1
4.	Is the economic study design appropriate to the stated objective?	1	1	1	1	1	1
5.	Are the structural assumptions and the validation methods of the model properly reported (models)?	NA	1	1	1	NA	NA
6.	Is the chosen time horizon appropriate in order to include relevant costs and consequences?	1	1	1	1	0	1
7.	Is the actual perspective chosen appropriate?	1	0.5	0.5	0.5	1	0.5
8.	Are all important and relevant costs for each alternative identified?	0.5	1	1	1	0	1
9.	Are all costs measured appropriately in physical units?	0.5	1	1	1	0.5	1
10.	Are costs valued appropriately?	1	1	0.5	1	0	1
11.	Are all important and relevant outcomes for each alternative identified?	1	1	1	1	1	1
12.	Are all outcomes measured appropriately?	0	1	1	1	1	1
13.	Are outcomes valued appropriately?	NA	1	1	1	1	1
14.	Is an appropriate incremental analysis of costs and outcomes of alternatives performed?	1	1	1	1	1	1
15.	Are all future costs and outcomes discounted appropriately?	0	1	1	1	0	NA
16.	Are all important variables. whose values are uncertain. appropriately subjected to sensitivity analysis?	0.5	0.5	0.5	0.5	0	1
17.	Do the conclusions follow from the data reported?	1	1	1	1	1	1
18.	Does the study discuss the generalizability of the results to other settings and patient/client groups?	1	1	1	1	1	0.5
19.	Does the article/ report indicate that there is no potential conflict of interest of study researcher(s) and funder(s)?	1	0	0.5	1	1	1
20.	Are ethical and distributional issues discussed appropriately?	1	0	0	1	0	0
Score (%)		78	83	83	93	63	89

Supplementary Table S2. Continued.

Item	Authors, year											
	Farag et al. 2014	Farag et al. 2015	Frick et al. 2010	Heinrich et al. 2013	Hendriks et al. 2008	Irvine et al. 2010	Jenkyn et al. 2012	Lee et al. 2013	McLean et al. 2015	Mori et al. 2017	Müller et al. 2014	Munro et al. 2004
1.	1	1	0	1	1	1	0.5	1	1	1	1	1
2.	1	1	1	0.5	1	1	1	1	1	1	0.5	0.5
3.	1	1	1	1	1	1	1	1	1	1	1	1
4.	1	1	1	1	1	1	1	1	1	1	1	1
5.	0.5	NA	0	NA	NA	NA	NA	1	1	1	1	NA
6.	1	1	1	1	1	1	1	1	1	1	1	1
7.	0.5	0.5	0.5	0.5	1	0.5	1	1	0.5	1	0.5	0.5
8.	1	1	1	1	1	1	0.5	1	1	1	1	0
9.	1	1	1	1	1	1	1	1	1	1	1	0.5
10.	1	1	1	1	1	1	1	1	1	1	1	0
11.	1	1	1	1	1	1	1	1	1	1	1	1
12.	1	1	1	1	1	1	1	1	1	1	1	1
13.	0	1	0	1	1	1	NA	0	1	1	1	1
14.	1	1	0.5	1	1	1	1	1	1	1	1	1
15.	0	NA	1	NA	NA	NA	NA	1	1	1	1	NA
16.	1	1	0.5	1	1	1	0	1	0.5	1	1	1
17.	1	1	0.5	1	1	1	1	1	1	1	1	1
18.	0	1	0.5	0.5	0.5	1	1	1	1	1	0.5	0.5
19.	1	1	1	1	0.5	0.5	0	1	1	0.5	0	1
20.	0	0	0	0	0	0.5	0.5	0	1	0	0	0
Score (%)	75	92	68	86	89	92	79	90	95	93	83	72

Supplementary Table S2. Continued.

Item	Patil et al. 2016	Peeters et al. 2011	Pega et al. 2016	Poole et al. 2015	Rizzo et al. 1996	Robertson et al. 2001 (1)	Robertson et al. 2001 (2)	Robertson et al. 2001 (3)	Sach et al. 2007	Sahlen et al. 2008	Salkeld et al. 2000	Smith et al. 1998	Van Haastregt et al. 2013
1.	1	1	1	1	1	1	1	1	1	1	1	1	1
2.	1	1	1	0.5	1	1	0.5	0.5	1	0.5	1	0.5	1
3.	1	1	1	1	1	1	1	1	1		1	0	1
4.	1	1	1	1	1	1	1	1	1	1	1	1	1
5.	NA	NA	1	1	NA	NA	NA	NA	NA	NA	NA	1	NA
6.	1	1	1	1	0	1	1	1	1	1	1	1	1
7.	1	1	0.5	0.5	0	1	1	1	1	1	1	1	1
8.	0.5	1	1	1	1	0.5	0.5	0.5	1	1	0.5	1	1
9.	1	1	1	1	1	1	1	1	1	1	1	1	1
10.	1	1	1	0.5	0.5	1	1	1	1	1	1	1	1
11.	1	1	1	1	1	1	1	1	1	1	1	1	1
12.	1	1	1	1	1	1	1	1	1	1	1	1	1
13.	NA	1	0	1	NA	NA	NA	NA	1	1	NA	NA	NA
14.	1	1	1	1	1	1	1	1	1	1	1	1	1
15.	NA	NA	1	0	NA	NA	NA	NA	NA	1	NA	1	0.5
16.	1	1	0	0	0.5	0.5	0.5	0.5	1	0	0.5	1	1
17.	1	1	1	1	0	1	1	1	1	1	1	1	1
18.	1	1	1	0.5	0.5	1	1	1	0	0.5	1	0	0.5
19.	1	0.5	1	1	0	1	1	1	1	0	0.5	0	1
20.	1	0	0	0	0	1	1	1	0	1	0	0	1
Score (%)	97	92	83	75	62	94	91	91	89	84	85	76	94

NA: Not applicable; Score 0: ‘No’; Score 0.5: ‘Suboptimal’; Score 1: ‘Yes’.

4

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

Authors, year	(Program), study population	Study design (economic evaluation)	Perspective	Time horizon
Exercise programs				
Church et al. 2011	65+, community-dwelling	Markov model (MBEE)	Healthcare[b]	10 years
Church et al. 2012	65+, community-dwelling and living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Davis et al. 2011	65-75, community-dwelling	RCT (TBEE)	Healthcare	9 months
Farag et al. 2015	60+, community-dwelling	RCT (TBEE)	Health and community service provider	1 year
McLean et al. 2015	70+, community-dwelling	Decision tree model (MBEE)	Healthcare	18 months
Munro et al. 2004	65+, community-dwelling	Pragmatic, cluster randomized community program trial (TBEE)	Healthcare	5 years
Robertson et al. 2001 (1)	80+, community-dwelling	RCT (TBEE)	Societal	2 years
Robertson et al. 2001 (2)	75+, community-dwelling	RCT (TBEE)	Societal	1 year
Robertson et al. 2001	80+, community-dwelling	RCT (TBEE)	Societal	1 year

Discount rate[a]	Powered for falls	Baseline fall risk	ICER (2016 US$)
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $186 / fall prevented (Tai Chi) CEA: $3,824 / fall prevented (group-based exercise) CEA: $1,543 / fall prevented (home based exercise) CUA: $34,847 / QALY (Tai Chi) CUA: $56,500 / QALY (group-based exercise) CUA: $74,701 / QALY (home based exercise)
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk not retrievable from paper or references	CEA: $3,370 / fall prevented (group-based exercise, general population) CEA: $1,957 / fall prevented (group-based exercise, high risk population) CEA: $4,446 / fall prevented (home based exercise) CEA: $2,103 / fall prevented (Tai Chi) CUA $48,093 / QALY (group-based exercise, general population) CUA $34,584 / QALY (group-based exercise, high risk population) CUA $63,436 / QALY (home based exercise) CUA $30,013 / QALY (Tai Chi)
NA	No, for improvement in training	0.78 (fall rate comparator)[c]	CEA + CUA: Cost saving (ICERs NR)
NA	Yes[55]	0.18 (fall rate comparator)[c]	CEA: $15,587 / improvement in mobility CEA: $12,914 / improvement in self-reported health CUA: $52,553 / QALY
3% for costs and outcomes	NA	0.443	CEA: $1,024 / fall prevented CEA: $1,847 / injurious fall prevented CUA: $80,860 / QALY
NR	No, for improvement in SF-36	No baseline risk specified and not to be derived from results section	CUA: $32,139 / QALY
NR	Yes	0.65 (152/223, fall rate in previous year comparator)[c]	CEA: $256 / fall prevented CEA: $411 / injurious fall prevented
NA	Yes	0.32 (45/114, fall fate in previous year comparator)[c]	CEA: $1,740 / fall prevented
NA	Yes	0.10 (45/450, fall rate in previous year comparator)[c]	CEA: $1,466 / fall prevented

Supplementary Table S3. Continued.

Authors, year	(Program), study population	Study design (economic evaluation)	Perspective	Time horizon
Home assessment programs				
Campbell et al. 2005	75+, community-dwelling	RCT (TBEE)	Societal	1 year
Church et al. 2012	65+, community-dwelling and living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Pega et al. 2016	65+, community-dwelling	Markov model (MBEE)	Healthcare	Lifetime
Sahlen et al. 2008	75+, community-dwelling	RCT (TBEE)	Societal	4 years
Salkeld et al. 2000	65+, community-dwelling	RCT (TBEE)	Societal	1 year
Smith et al. 1998	75+, community-dwelling	Decision tree model (MBEE)	Healthcare	10 years
Medication adjustment programs				
Church et al. 2011	65+, community-dwelling	Markov model (MBEE)	Healthcare[b]	10 years
	65+, living in a residential care facility	Markov model (MBEE)	Healthcare[b]	10 years
Church et al. 2012	65+, community-dwelling and living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Church et al. 2015	Older adults (mean age ± 84 years), living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime

Discount rate[a]	Powered for falls	Baseline fall risk	ICER (2016 US$)
NA	Yes	0.69 (271/391, fall rate comparator)[c]	CEA: $548 / fall prevented[d]
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk not retrievable from paper or references	CEA: $2,224 / fall prevented CUA: $39,281 / QALY
3% for costs and outcomes	NA	Low risk (no history of falls) and high risk (history of falls)	CUA: $6,461 / QALY
3% for costs and outcomes	NR	No baseline risk specified and not to be derived from results section	CUA: $2,158 / QALY
NA	Yes[56]	0.19 (103/530, fall rate in the previous year comparator)[c]	CEA: $5,313 / fall prevented
5% for costs and outcomes	NA	0.4	CEA: $1,834 / fall prevented CEA: $18,335 / injury prevented
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $872 / fall prevented CUA: $12,877 / QALY
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA + CUA: Cost saving
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk not retrievable from paper or references	CEA: $818 / fall prevented CUA: $11,683 / QALY
5% for costs and outcomes	NA	Low 0.495, medium 0.395, high 0.110.	CEA + CUA: Cost saving

Supplementary Table S3. Continued.

Authors, year	(Program), study population	Study design (economic evaluation)	Perspective	Time horizon
Frick et al. 2010	Older adults (age unknown), community-dwelling	Epidemiology based model (MBEE)	Healthcare	Lifetime
Multifactorial programs				
Church et al. 2011	65+, community-dwelling	Markov model (MBEE)	Healthcare[b]	10 years
	65+, living in a residential care facility	Markov model (MBEE)	Healthcare[b]	10 years
Church et al. 2012	65+, community-dwelling and living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Church et al. 2015	Older adults (mean age ± 84 years), living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Farag et al. 2014	65+, community-dwelling	Markov model (MBEE)	Health funder	Lifetime
Heinrich et al. 2013	65+, living in a residential care facility	Non-randomized cluster trial (TBEE)	Payer	1 year
Hendriks et al. 2008	65+, community-dwelling	RCT (TBEE)	Societal	1 year

Discount rate[a]	Powered for falls	Baseline fall risk	ICER (2016 US$)
3% for costs and outcomes	NA	Model based on fractures rates	CUA: Least expensive and most effective, compared with exercise, home assessment, multifactorial, and vitamin D programs (ICERs NR)
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $4,625 / fall prevented (multiple program) CEA: $7,589 / fall prevented (multifactorial – active) CEA: $1,763 / fall prevented (multifactorial – referral) CUA: $57,604 / QALY (multiple program) CUA: $101,050 / QALY (multifactorial – active) CUA: $133,561 / QALY (multifactorial – referral)
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $2,064 / fall prevented (multiple program) CEA: $2,589 / fall prevented (multifactorial – active) CUA: $35,164 / QALY (multiple program) CUA: $44,067/ QALY (multifactorial – active)
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk not retrievable from paper or references	CEA: $3,440 / fall prevented (multiple program) CEA: $5,990 / fall prevented (multifactorial – active) CEA: $7,883 / fall prevented (multifactorial – referral) CEA: $3,467 / fall prevented (multifactorial, high risk population) CUA: $49,092/ QALY (multiple program) CUA: $85,458 / QALY (multifactorial – active) CUA: $112,598 / QALY (multifactorial – referral) CUA: $61,260 / QALY (multifactorial, high risk population)
5% for costs and outcomes	NA	Low 0.495, medium 0.395, high 0.110	CEA: $1,666 / fall prevented CUA: $28,437/ QALY
NR	NA	0.270, history of falls 0.390	CUA: $20,427 / QALY
NA	No, for hip fractures[57]	No baseline risk specified and not to be derived from results section	CEA: $9,951 / year free of femoral fracture
NA	Yes	0.33 (82/249, more than one fall (rate) in the previous year comparator)[c]	CEA: $-8,220 / fall prevented CUA: $13,012 / QALY The program was less effective and more costly than the control condition

4

Supplementary Table S3. Continued.

Authors, year	(Program), study population	Study design (economic evaluation)	Perspective	Time horizon
Irvine et al. 2010	70+, community-dwelling	RCT (TBEE)	NHS and personal social services	1 year
Jenkyn et al. 2012	Older adults (mean age ± 80 years), community-dwelling	RCT (TBEE)	Societal	1 year
Müller et al. 2014	80+, living in a residential care facility	Markov model (MBEE)	SHI and LCI	20 years
Peeters et al. 2011	65+, community-dwelling	RCT (TBEE)	Societal	1 year
Rizzo et al. 1996	70+, community-dwelling	RCT (TBEE)	Healthcare[b]	NR
Other programs				
Church et al. 2011	Vitamin D supplementation, 65+, living in a residential care facility	Markov model (MBEE)	Healthcare[b]	10 years
Church et al. 2015	Vitamin D supplementation, older adults (mean age ± 84 years), living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Lee et al. 2013	Vitamin D screening, 65-80, community-dwelling	Markov model (MBEE)	Societal[e]	3 years
Patil et al. 2016	Vitamin D supplementation and exercise, 70-80, community-dwelling	RCT (TBEE)	Societal	2 years
Poole et al. 2015	Vitamin D supplementation, 60+, community-dwelling	Markov model (MBEE)	Payer	5 years
Church et al. 2011	Cataract surgery, 65+, community-dwelling	Markov model (MBEE)	Healthcare[b]	10 years

Discount rate[a]	Powered for falls	Baseline fall risk	ICER (2016 US$)
NA	Yes[58]	High risk, based on a modified version of the Falls Risk Assessment Tool	CEA: $5,414 / fall prevented
NA	NR	0.15 (52/348, more than one fall (rate) in the previous year comparator)[c]	CEA: $125,909 / fall prevented
3% for costs and outcomes	NA	Model based on fracture rates	CUA: $28,369 / QALY
NA	Yes	High risk, LASA 8 or higher	CEA: $304 / percentage decrease in falls CEA: $-376 / percentage recurrent falls CUA: $-312,671 / QALY The program was less effective and more costly than the control condition
NR	NR	Low risk and high risk, based on age and no. of prescriptions	CEA: $2,996 / fall prevented
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $5 / fall prevented CUA: $82 / QALY
5% for costs and outcomes	NA	Low 0.495, medium 0.395, high 0.110	CEA + CUA: Cost saving
3% for costs and outcomes	NA	Baseline risk age and sex dependent: male (13.6-20.1), female (13.9-21.0)[c]	CBA: NMB $239 versus $202 (women) CBA: NMB $318 versus $277 (men)
NR	Yes	0.75 (229/307, fall rate in the previous two years comparator)[c]	CEA: $5,549 / injurious fall prevented
NR	NA	Baseline risk age and sex dependent: male (13.6-20.1), female (13.9-21.0)[c]	CUA: $28,906 / QALY
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $119 / fall prevented CUA: $1,717 / QALY

Supplementary Table S3. Continued.

Authors, year	(Program), study population	Study design (economic evaluation)	Perspective	Time horizon
Church et al. 2012	Cataract surgery, 65+, community-dwelling and living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Sach et al. 2007	Cataract surgery, 70+, community-dwelling and living in a residential care facility	RCT (TBEE)	NHS and personal social services	1 year
Church et al. 2011	Cardiac pacing, 65+, community-dwelling	Markov model (MBEE)	Healthcare[b]	10 years
Church et al. 2012	Cardiac pacing, 65+, community-dwelling and living in a residential care facility	Markov model (MBEE)	Healthcare[b]	Lifetime
Cockanye et al. 2017	Podiatry care, 65+, community-dwelling	Cohort RCT (TBEE)	NHS and societal	NR
Mori et al. 2017	Bisphosphonates and exercise, 65+, community-dwelling	Markov micro simulation model (MBEE)	Societal	Lifetime
Van Haastregt et al. 2013	Cognitive behavioural, 70+, community-dwelling	RCT (TBEE)	Societal	14 months

CBA: Cost-benefit analysis; CEA: Cost-effectiveness analysis; CUA: Cost-utility analysis; ICER: Incremental cost-effectiveness ratio; LCI: Long-term care insurance; MBEE: Model-based economicevaluation; NA: Not applicable; NHS: National Health Service (UK); NMB: Net monetary benefit; NR: Not reported; RCT: Randomized controlled trial; SHI: Statutory health insurance; TBEE: Trial-based economic evaluation.

[a] Discount rates are not applicable to studies with a time horizon of one year and shorter, NR was reported for studies in which discounting was not applied when the time horizon exceeded one year.

[b] Perspective is not reported, but is derived from the method section of the article.

[c] Baseline fall risk is not reported, but is derived from the method section of the article.

[d] Unclear which program(s) and comparator was included in the cost-effectiveness analysis.

[e] Perspective defined as societal, but only healthcare costs were considered in the analysis.

Discount rate[a]	Powered for falls	Baseline fall risk	ICER (2016 US$)
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk not retrievable from paper or references	CEA + CUA: Cost saving
NA	Yes	0.39 (Fall rate comparator)[c]	CEA: $7,360 / fall prevented CUA: $65,978 / QALY
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk age dependent: low (0.18-0.31), medium (0.25-0.50), high (0.39-0.69)	CEA: $3,529 / fall prevented CUA: $62,318 / QALY
5% for costs and outcomes	NA	Low, medium, and high risk included. Baseline risk not retrievable from paper or references	CEA: $2,194 / fall prevented CUA: $38,097 / QALY
NR	Yes	0,32 (323/1,010, more than one fall (rate) in the previous year comparator)[c]	CEA: $1,807 / fall prevented CUA: $28,089-29,673 / QALY
3% for costs and outcomes	NA	Model based on fracture rates	CUA: $204,810 / QALY (age 65) CUA: $120,096 / QALY (age 70) CUA: $47,517 / QALY (age 75) CUA: $17,884 / QALY (age 80)
NR	No, for fall-related self-efficacy[59]	0.20 (106/540), at least one fall (rate) in the previous six months comparator)[c]	CEA: $1,498 / patient not afraid of falling CEA: $956 / patient not avoiding activity

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

	Costs			Uncertainty	
Authors, year	**Identification cost categories**	**Measurement**	**Valuation sources**	**Sampling**	**Sensitivity analysis**
Campbell et al. 2005	Program, healthcare	Trial records	Reported	NR	Yes
Cockanye et al. 2017	NR	Questionnaire	NR	NR	NR
Davis et al. 2011	Program, healthcare	Questionnaire	Reported	Bootstrapping	Yes
Farag et al. 2015	Program, healthcare	Calendars, telephone interview	Reported	Bootstrapping	Yes
Heinrich et al. 2013	Program, healthcare	Sickness fund database	Reported	Bootstrapping	Yes
Hendriks et al. 2008	Program, healthcare, patient and family	Diaries, telephone interview	Reported	Bootstrapping	Yes
Irvine et al. 2010	Program, healthcare	Questionnaire, patient database	Reported	Bootstrapping	Yes
Jenkyn et al. 2012	Program, healthcare	Telephone interview	Reported	NR	NR
Munro et al. 2004	Program, healthcare	Unclear	NR	Bootstrapping	Yes
Patil et al. 2016	Program, healthcare	Patient database	Reported	Bootstrapping	Yes
Peeters et al. 2011	Program, healthcare, patient and family	Questionnaire	Reported	Bootstrapping	Yes
Rizzo et al. 1996	Program, healthcare	Patient database	Reported	NR	Yes
Robertson et al. 2001 (1)	Program, healthcare	Study records, patient database	Reported	NR	Yes
Robertson et al. 2001 (2)	Program, healthcare	Study records, patient database	Reported	NR	Yes
Robertson et al. 2001 (3)	Program, healthcare	Study records, patient database	Reported	NR	Yes
Sach et al. 2007	Program, healthcare, informal care	Diaries, telephone interview	Reported	Bootstrapping	Yes
Sahlen et al. 2008	Program, healthcare	Municipality records, patient database	Reported	NR	NR
Salkeld et al. 2000	Program, healthcare, informal care	Patient database	Reported	NR	Yes
Van Haastregt et al. 2013	Program, healthcare, patient and family	Questionnaire, telephone interview	Reported	Bootstrapping	Yes

NR: Not reported.

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

	Costs		Uncertainty
Authors, year	**Identification cost categories**	**Valuation sources**	**Sensitivity analysis**
Church et al. 2011	Program, healthcare	Reported	Probabilistic
Church et al. 2012	Program, healthcare	Reported	Probabilistic
Church et al. 2015	Program, healthcare	Reported	Probabilistic
Farag et al. 2014	Program, healthcare	Reported	Probabilistic and deterministic
Frick et al. 2010	Program, healthcare	Reported	Probabilistic
Lee et al. 2013	Program, healthcare	Reported	Probabilistic and deterministic
McLean et al. 2015	Program, healthcare	Reported	Probabilistic
Mori et al. 2017	Program, healthcare	Reported	Probabilistic and deterministic
Müller et al. 2014	Program, healthcare	Reported	Probabilistic and deterministic
Pega et al. 2016	Program, healthcare	Reported	NR
Poole et al. 2015	Program, healthcare	Reported	NR
Smith et al. 1998	Program, healthcare	Reported	Probabilistic

NR: Not reported.

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

Embase

(‘economic evaluation’/exp OR ‘program cost effectiveness’/exp OR ‘economic aspect’/de OR economics/de OR cost/de OR ‘health care cost’/exp OR ‘health care utilization’/exp OR (((econom* OR cost* OR macroeconom*) NEAR/6 (evaluat* OR evaluat* OR analy* OR effect* OR control* OR benefit* OR minimi* OR saving* OR saver* OR reduc* OR societ* OR Healthcare* OR care OR model* OR consequence* OR hospital* OR intens* OR institute* OR admission* OR ‘nursing home’ OR ‘nursing homes’ OR ‘public health’ OR ‘health system’ OR utilit* OR low* OR high*)) OR ((econom* OR macroeconom*) NEAR/3 cost*) OR ((‘health care’ OR healthcare) NEAR/3 (utilizat* OR utilisat*))):ab,ti) AND (falling/exp OR ‘fall risk’/exp OR ‘fall risk assessment’/exp OR (fall OR falls OR falling OR slip OR slips OR slipping):ab,ti) AND (prevention/exp OR prevention:lnk OR ‘risk reduction’/exp OR (prevent* OR protect* OR avoid* OR ((decreas* OR reduc* OR rate*) NEAR/3 (fall* OR number* OR inciden* OR risk*))):ab,ti) AND (aged/exp OR aging/exp OR dementia/exp OR ‘nursing home’/exp OR ‘elderly care’/exp OR ‘residential home’/exp OR ‘nursing home patient’/exp OR geriatrics/exp OR gerontology/exp OR ‘geriatric patient’/exp OR (((aged OR old*) NEAR/3 (person* OR people* OR men OR women OR patient* OR subject* OR adult*)) OR (old* NEXT/1 age*) OR senior* OR elderl* OR ((communit* OR home OR institut*) NEAR/3 (dwell* OR living)) OR (nursing NEXT/1 home*) OR geriatr* OR (home* NEAR/3 aged) OR ((residential OR ‘long term’) NEXT/3 (home* OR institute* OR facilit*)) OR ageing OR aging OR dement* OR gerontolog*):ab,ti)

Medline Ovid

(exp Costs and Cost Analysis/ OR economics.xs. OR economics/ OR (((econom* OR cost* OR macroeconom*) ADJ6 (evaluat* OR analy* OR effect* OR control* OR benefit* OR minimi* OR saving* OR saver* OR reduc* OR societ* OR Healthcare* OR care OR model* OR consequence* OR hospital* OR intens* OR institute* OR admission* OR nursing home OR nursing homes OR public health OR health system OR utilit* OR low* OR high*)) OR ((econom* OR macroeconom*) ADJ3 cost*) OR ((health care OR healthcare) ADJ3 (utilizat* OR utilisat*))).ab,ti.) AND (Accidental Falls/ OR (fall OR falls OR falling OR slip OR slips OR slipping).ab,ti.) AND (“prevention and control”.xs. OR Preventive Health Services/ OR Primary Prevention/ OR Secondary Prevention/ OR Tertiary Prevention/ OR Risk Reduction Behavior/ OR (prevent* OR protect* OR avoid* OR ((decreas* OR reduc* OR rate*) ADJ3 (fall* OR number* OR inciden* OR risk*))).ab,ti.) AND (exp aged/ OR exp aging/ OR exp dementia/ OR Housing for the Elderly/ OR exp Residential Facilities/ OR geriatrics/ OR Geriatric Nursing/ OR (((aged OR old*) ADJ3 (person* OR people* OR men OR women OR patient* OR subject* OR adult*)) OR (old* ADJ age*) OR senior* OR elderl* OR ((communit* OR home OR institut*) ADJ3 (dwell* OR living)) OR (nursing ADJ home*) OR geriatr* OR (home* ADJ3 aged) OR ((residential OR long term) ADJ3 (home* OR institute* OR facilit*)) OR ageing OR aging OR dement* OR gerontolog*).ab,ti.)

Web of science

TS=(((((econom* OR cost* OR macroeconom*) NEAR/6 (evaluat* OR analy* OR effect* OR control* OR benefit* OR minimi* OR saving* OR saver* OR reduc* OR societ* OR Healthcare* OR care OR model* OR consequence* OR hospital* OR intens* OR institute* OR admission* OR “nursing home”

OR “nursing homes” OR “public health” OR “health system” OR utilit* OR low* OR high*)) OR ((econom* OR macroeconom*) NEAR/3 cost*) OR ((“health care” OR healthcare) NEAR/3 (utilizat* OR utilisat*)))) AND ((fall OR falls OR falling OR slip OR slips OR slipping)) AND ((prevent* OR protect* OR avoid* OR ((decreas* OR reduc* OR rate*) NEAR/3 (fall* OR number* OR inciden* OR risk*)))) AND ((((aged OR old*) NEAR/3 (person* OR people* OR men OR women OR patient* OR subject* OR adult*)) OR (old* NEAR/1 age*) OR senior* OR elderl* OR ((communit* OR home OR institut*) NEAR/3 (dwell* OR living)) OR (nursing NEAR/1 home*) OR geriatr* OR (home* NEAR/3 aged) OR ((residential OR “long term”) NEAR/3 (home* OR institute* OR facilit*)) OR ageing OR aging OR dement* OR gerontolog*)))

Cochrane

((((econom* OR cost* OR macroeconom*) NEAR/6 (evaluat* OR analy* OR effect* OR control* OR benefit* OR minimi* OR saving* OR saver* OR reduc* OR societ* OR Healthcare* OR care OR model* OR consequence* OR hospital* OR intens* OR institute* OR admission* OR ‘nursing home’ OR ‘nursing homes’ OR ‘public health’ OR ‘health system’ OR utilit* OR low* OR high*)) OR ((econom* OR macroeconom*) NEAR/3 cost*) OR ((‘health care’ OR healthcare) NEAR/3 (utilizat* OR utilisat*))):ab,ti) AND ((fall OR falls OR falling OR slip OR slips OR slipping):ab,ti) AND ((prevent* OR protect* OR avoid* OR ((decreas* OR reduc* OR rate*) NEAR/3 (fall* OR number* OR inciden* OR risk*))):ab,ti) AND ((((aged OR old*) NEAR/3 (person* OR people* OR men OR women OR patient* OR subject* OR adult*)) OR (old* NEXT/1 age*) OR senior* OR elderl* OR ((communit* OR home OR institut*) NEAR/3 (dwell* OR living)) OR (nursing NEXT/1 home*) OR geriatr* OR (home* NEAR/3 aged) OR ((residential OR ‘long term’) NEXT/3 (home* OR institute* OR facilit*)) OR ageing OR aging OR dement* OR gerontolog*):ab,ti)

CINAHL EBSCO

(MH “Costs and Cost Analysis+” OR MW economics OR MH economics OR (((econom* OR cost* OR macroeconom*) N6 (evaluat* OR analy* OR effect* OR control* OR benefit* OR minimi* OR saving* OR saver* OR reduc* OR societ* OR Healthcare* OR care OR model* OR consequence* OR hospital* OR intens* OR institute* OR admission* OR nursing home OR nursing homes OR public health OR health system OR utilit* OR low* OR high*)) OR ((econom* OR macroeconom*) N3 cost*) OR ((health care OR healthcare) N3 (utilizat* OR utilisat*)))) AND (MH “Accidental Falls+” OR (fall OR falls OR falling OR slip OR slips OR slipping)) AND (MW prevention OR (prevent* OR protect* OR avoid* OR ((decreas* OR reduc* OR rate*) N3 (fall* OR number* OR inciden* OR risk*)))) AND (MH aged+ OR MH aging+ OR MH dementia+ OR MH “Housing for the Elderly+” OR MH “Residential Facilities+” OR MH geriatrics+ OR MH “Gerontologic Nursing+” OR (((aged OR old*) N3 (person* OR people* OR men OR women OR patient* OR subject* OR adult*)) OR (old* n1 age*) OR senior* OR elderl* OR ((communit* OR home OR institut*) N3 (dwell* OR living)) OR (nursing n1 home*) OR geriatr* OR (home* N3 aged) OR ((residential OR long term) N3 (home* OR institute* OR facilit*)) OR ageing OR aging OR dement* OR gerontolog*))

PyscINFO Ovid

(exp “Costs and Cost Analysis”/ OR economics/ OR (((econom* OR cost* OR macroeconom*) ADJ6 (evaluat* OR analy* OR effect* OR control* OR benefit* OR minimi* OR saving* OR saver* OR reduc* OR societ* OR Healthcare* OR care OR model* OR consequence* OR hospital* OR intens* OR institute* OR admission* OR nursing home OR nursing homes OR public health OR health system OR utilit* OR low* OR high*)) OR ((econom* OR macroeconom*) ADJ3 cost*) OR ((health care OR healthcare) ADJ3 (utilizat* OR utilisat*))).ab,ti.) AND (Falls/ OR (fall OR falls OR falling OR slip OR slips OR slipping).ab,ti.) AND (exp prevention/ OR exp Preventive Medicine/ OR (prevent* OR protect* OR avoid* OR ((decreas* OR reduc* OR rate*) ADJ3 (fall* OR number* OR inciden* OR risk*))).ab,ti.) AND (380.ag. OR 390.ag. OR exp aging/ OR exp dementia/ OR exp Residential Care Institutions/ OR geriatrics/ OR (((aged OR old*) ADJ3 (person* OR people* OR men OR women OR patient* OR subject* OR adult*)) OR (old* ADJ age*) OR senior* OR elderl* OR ((communit* OR home OR institut*) ADJ3 (dwell* OR living)) OR (nursing ADJ home*) OR geriatr* OR (home* ADJ3 aged) OR ((residential OR long term) ADJ3 (home* OR institute* OR facilit*)) OR ageing OR aging OR dement* OR gerontolog*).ab,ti.)

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Supplementary Text S2. CHEC extended scoring instruction.

This instruction applies to the extended version of the Consensus on Health Economic Criteria (CHEC) checklist (Evers at al., 2005).

Scoring options:

0 = No

0,5 = Suboptimal

1 = Yes

NA = Not applicable

- TBEE: trial-based economic evaluation
- MBEE: model-based economic evaluation
- Only score 'Unclear' when none of the other options is appropriate

General remark: when authors refer to another article for certain information (for example inclusion and exclusion criteria), score 0,5 when it is clear what specific information is described in another article, and 0 when it is not clear what specific information is described in another article. Only data from the included articles will be checked, not referred articles.

CHEC instruction:

1. Is the study population clearly described?

TBEE: Are the clinical characteristics, eligibility, entry and follow-up mentioned?

Clinical characteristics including eligibility, entry and follow-up described: 1

Clinical characteristics, eligibility, entry and follow-up not completely described: 0,5

No description: 0

MBEE: Are the clinical characteristics of the (hypothetical) population described?

Completely described: 1

Not clearly described: 0,5

Not described: 0

2. Are competing alternatives clearly described?

Are the alternative interventions described completely, including duration/intensity?

All aspects completely described: 1

Mentioned but not clearly described: 0,5

Neither mentioned nor described: 0

3. Is a well-defined research question posed in answerable form?

Is a clear question/objective described? Are the population and interventions included in the research question/objective? This does not have to be a literal question; clear aims or objectives are also sufficient.

Clear research question: 1

Incomplete research question: 0,5

No research questioned mentioned: 0

4. Is the economic study design appropriate to the stated objective?

Are both costs and effects of 2 or more interventions compared?

A score of 1 must be assigned; otherwise the study is excluded from the review.

5. Are the structural assumptions and the validation methods of the model properly reported? (MBEE only)

Is the structure of the model clearly described and/or depicted, and are the assumptions explained properly?
Model structure is clear and assumptions discussed: 1
Only model structure or assumptions discussed: 0,5
Not reported: 0
6. Is the chosen time horizon appropriate in order to include relevant costs and consequences?
Time horizon not mentioned: 0
Societal perspective study: a time horizon <1 year is short.
Time horizon 1 year or beyond: 1
Time horizon 6 months - 1 year: 0,5
Time horizon < 6 months: 0
Healthcare perspective: a time horizon <1 year is common, but it depends on the context whether it is appropriate.
7. Is the actual perspective chosen appropriate?
This item is only for the mentioning of the perspective, not the actual perspective!
When the perspective is narrower than societal, a justification must be provided.
Societal: 1
Perspective not explicitly mentioned: 0
Other/Perspective narrower than societal, but not explained: 0,5
8. Are all important and relevant costs for each alternative identified?
Healthcare perspective
Only intervention/program costs: 0
Intervention/program costs and other healthcare costs: 1
Societal perspective
Only intervention/program costs: 0
Intervention/program costs and healthcare costs: 0,5
Intervention/program costs and healthcare costs + costs beyond healthcare: 1
9. Are all costs measured appropriately in physical units?
TBEE:
Is it clear how costs are measured? Interview, questionnaire etc.
MBEE:
Are the sources of cost data clear and appropriate?
Mentioned and appropriate: 1
Mentioned but inappropriate: 0,5
Not mentioned: 0
10. Are costs valued appropriately?
Are the sources of valuation including the reference year mentioned for ALL cost categories?
Sources and reference/index year mentioned: 1
Sources described but no reference/index year: 0,5
Sources not mentioned: 0
Note:
When tariffs or extrapolation are used the score is never 1.

Valuation partly based on tariffs or extrapolation: 0,5
Only tariffs used for all cost categories: 0
11. Are all important and relevant outcomes for each alternative identified?
Are the outcomes relevant and do they fit the research question and perspective?
Outcomes identified and relevant: 1
Outcomes not identified/not relevant: 0
12. Are all outcomes measured appropriately?
TBEE:
Is the measurement instrument relevant and described?
MBEE:
Are the sources of the outcome parameters in the model clear and appropriate?
Relevant and described: 1
Described but not relevant: 0,5
Not clear/mentioned: 0
13. Are outcomes valued appropriately? (CUA/CBA only)
How are utilities derived (EQ-5D, SF-36, VAS, TTO, etc.)?
Valuation mentioned and appropriate: 1
Valuation mentioned but not appropriate: 0,5
Not mentioned: 0
14. Is an appropriate incremental analysis of costs and outcomes of alternatives performed?
Is an ICER calculated? (C2-C1/O2-O1) Only a description (e.g. intervention A has more effects at lower costs compared to B) is not sufficient.
Incremental analysis (C2-C1/O2-O1) performed: 1
Only (C2-C1) and (O2-O1) performed, but not divided by each other: 0,5
No incremental analysis of costs and outcomes: 0
15. Are all future costs and outcomes discounted appropriately?
Only for studies > 1 year time horizon.
< 1 year time horizon: NA
> 1 year time horizon:
Not discounted: 0
Discount rates are reported for both cost and effects (QALYs): 1
Discount rates only mentioned for costs or effects: 0,5
16. Are all important variables, whose values are uncertain, appropriately subjected to sensitivity analysis?
MBEE:
Probabilistic sensitivity analysis and deterministic sensitivity analysis: 1
Only probabilistic or deterministic sensitivity analysis: 0,5
None: 0
TBEE:
Sample uncertainty (bootstrapping) and additional sensitivity analysis performed: 1
Bootstrapping (sampling uncertainty) without additional sensitivity analysis: 0,5
Sensitivity analysis without bootstrapping: 0,5
No bootstrapping or additional sensitivity analysis: 0

17. Do the conclusions follow from the data reported?
Are the results interpreted correctly and cautiously, and are the conclusions supported by the data? For example, when it is concluded that a certain intervention is cost-effective only based on a point estimate (without bootstrapping and CEAC etc.) this is regarded inappropriate.
Appropriate conclusion: 1
No conclusion or inappropriate conclusion: 0
18. Does the study discuss the generalizability of the results to other settings and patient/client groups?
Is it addressed how results can vary in other populations, regions, settings?
Mentioned and discussed: 1
Mentioned: 0,5
None: 0
19. Does the article/ report indicate that there is no potential conflict of interest of study researcher(s) and funder(s)?
A conflict of interest statement does not have to be literal, when it is stated that authors receive grants for example, this is also sufficient.
When conflicts of interest and/or funding roles are disclosed FOR ALL AUTHORS: 1
When authors do have competing interests or receive grants etc., but it is clearly disclosed for all authors: 1
Not mentioned: score 0
Not clearly or partly disclosed: 0,5
20. Are ethical and distributional issues discussed appropriately?
Are ethical aspects regarding characteristics of the population or interventions discussed?
Mentioned and discussed: 1
Mentioned: 0,5
None: 0

Supplementary Text S3. Content of multifactorial falls prevention programs.

Church et al. 2011
Multiple program – Assessment and modification of risk factors, including group information sessions, and follow-up.
Multifactorial (active) – Assessment and modification of risk factors, including medication adjustment, exercise, home assessment, vision assessment, counselling, and follow-up.
Multifactorial (referral) – Assessment and modification of risk factors, including home assessment, interview by nurse, and follow-up.

Church et al. 2012
Multiple program – Not reported.
Multifactorial (active) – Not reported.
Multifactorial (referral) – Not reported.
Multifactorial (high risk population) – Not reported.

Church et al. 2015
Assessment and modification of risk factors, including medication adjustment, exercise, home assessment, vision assessment, education, and follow-up.

Farag et al. 2014
Assessment and tailored modification of risk factors, including exercise.

Hendriks et al. 2008
Assessment and tailored modification of risk factors, by medical and occupational therapy.

Peeters et al. 2011
Assessment and tailored modification of risk factors, including medication adjustment, exercise, home assessment, and referral to other specialists.

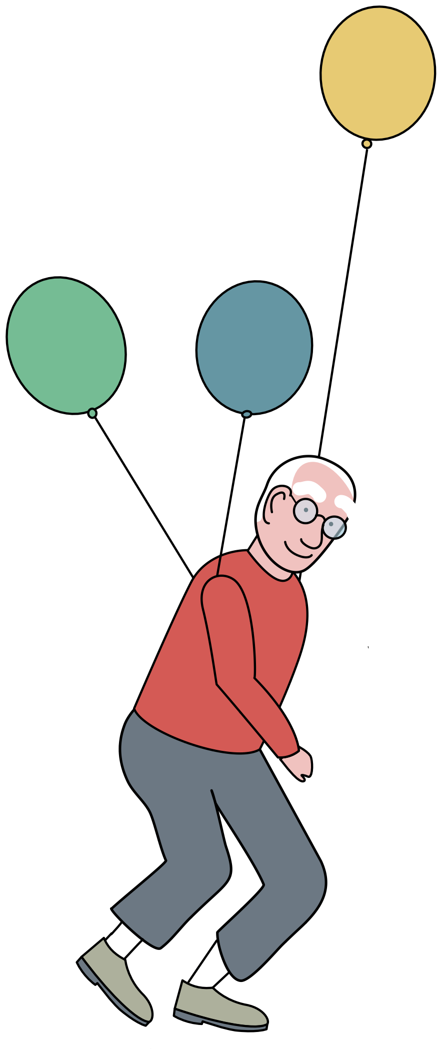
Irvine et al. 2010
Assessment and tailored modification of risk factors, including medication adjustment, exercise, home assessment, and referral to other specialists

Rizzo et al. 1996
Assessment and tailored modification of risk factors, including medication adjustment, exercise, home assessment, and behavioural changes.

Jenkyn et al. 2012
Assessment and tailored modification of risk factors, including medication adjustment, exercise, and foot problems.

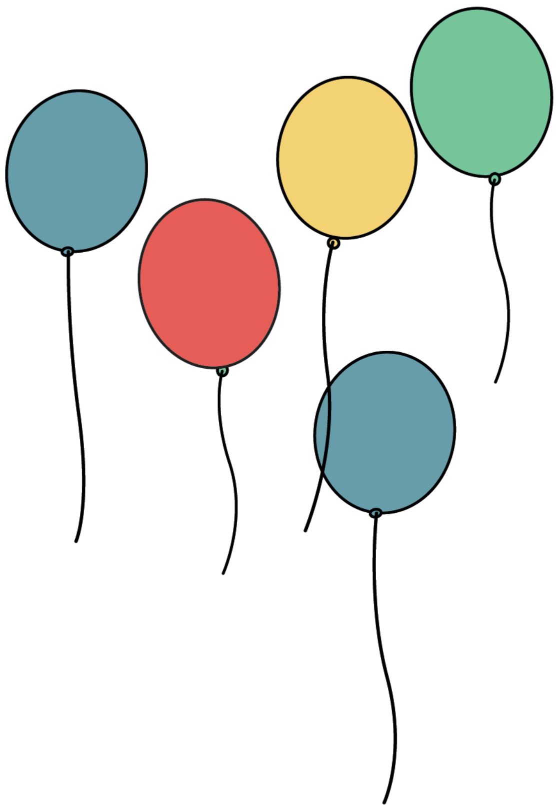
Heinrich et al. 2013
Assessment and tailored modification of risk factors, including exercise and home assessment.

Müller et al. 2014
Assessment and tailored modification of risk factors, including exercise, education, and hip protectors.



PART III

Falls prevention in a community setting



CHAPTER 5

Falls prevention activities among community-dwelling elderly in the Netherlands: A Delphi study

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Abstract

Introduction: This study aimed to provide an overview of the current falls prevention activities in community-dwelling elderly with an increased risk of falling in the Netherlands. Therefore, we determined: a) how health professionals detect community-dwelling elderly with an increased risk of falling; b) which falls prevention activities are used by health professionals and why; c) how elderly can be stimulated to participate in falls prevention programs; and d) how to finance falls prevention.
Methods: A two-round online Delphi study among health experts was conducted. The panel of experts (n = 125) consisted of community physiotherapists, community nurses, general practitioners, occupational therapists and geriatricians, from all over the Netherlands. The median and Inter Quartile Deviation (IQD) were reported for the questions with 5-point Likert scales, ranging from 'least' (1) to 'most' (5).
Results: Respectively 68% (n = 85/125) and 58% (n = 72/125) of the panel completely filled in the first and second round questionnaires. According to the panel, regular detection of fall risk of community-dwelling elderly with an increased risk of falling hardly takes place (median = 2 [hardly]; IQD = 1). Furthermore, these elderly are reluctant to participate in annual detection of fall risk (median = 3 [reluctant]; IQD = 1). According to 73% (n = 37/51) of the panel, 0–40% of the elderly with an increased risk of falling are referred to exercise programs. In general, the panel indicated that structural follow-up is often lacking. Namely, after one month (n = 21/43; 49%), three months (n = 24/42; 57%), and six months (n = 27/45; 60%) follow-up is never or hardly ever offered. Participation of elderly in falls prevention programs could be stimulated by a combination of measures. Should a combination of national health education, healthcare counselling, and removal of financial barriers be applied, 41–80% of the elderly is assumed to participate in falls prevention programs (n = 47/64; 73%). None of the panel members indicated full financing of falls prevention by the elderly. A number of individuals are considered key in falls prevention activities, such as the general practitioner, physiotherapist, and informal caregiver.
Conclusion: This Delphi study showed clear directions for improving falls prevention activities and how to increase participation rates.

1. Introduction

Falls are a prominent cause of global injury in elderly [1].Studies in the United States, Australia, and in European countries – like the United Kingdom and the Netherlands – have shown the magnitude of this problem [2-5]. Systematic reviews and meta-analyses have shown that the prevalence of falls in community-dwelling elderly can be largely reduced by offering exercise and multifactorial falls prevention programs [6, 7]. Furthermore, international guidelines on medication monitoring, vision control and correction, mapping fall risks in and around the house, and screening for and supplementation of vitamin D have been established [8]. These falls prevention programs are mainly successful when the target group is reached with effective, individually tailored programs that take into account the characteristics, issues, and preferences of the individual [9]. However, health professionals often lack the time and expertise to give elderly proper falls prevention advice [10]. Moreover, when falls prevention programs are offered, participation rates are low [11, 12]. Reasons indicated are a low risk perception, problems with mobility, and the distance and costs of travelling [13-15]. A high participation rate is vital in making a falls prevention program work in practice, and will depend on both generic factors and factors related to local context. In order to increase falls prevention participation rates in a community or country, an overview of the current falls prevention activities of health professionals and their views on potential improvements is necessary. This overview includes activities such as detection of fall risk, developing and offering falls prevention programs, offering supervision and follow-up, stimulating program participation, and financing falls prevention. This overview will be useful in developing and supporting successful falls prevention programs. To this end, we performed a Delphi study among a panel of health experts in the field of falls prevention in the Netherlands. The main research questions are:

- How do health professionals detect community-dwelling elderly with an increased risk of falling?
- Which falls prevention activities are used by health professionals and why?
- How can elderly be stimulated to participate in falls prevention programs?
- How can falls prevention be financed?

2. Materials and methods

2.1 Study design

Between March 2016 and May 2016, an online two-round Delphi study among a panel of health experts was conducted. The Delphi technique is composed of multiple questionnaire rounds, meant to reach consensus within a panel [16-18]. Consensus is reached by allowing a panel of experts to: 1) anonymously provide information; and 2) reflect on the information provided by other panel members [19].

2.2 Participants

The panel of health experts in the field of falls prevention was composed of different stakeholders, namely community physiotherapists, community nurses, general practitioners, occupational therapists, and geriatricians, from all over the Netherlands. We aimed at including healthcare experts mainly working at the community level. These individuals were recruited using purposive expert sampling. Apart from the project groups' personal expert network, experts were recruited through falls prevention websites and by approaching existing contacts of health professionals.

2.3 Questionnaires

At the beginning of the Delphi study, the panel of health experts received the first round online questionnaire. This questionnaire contained a general introduction on the studied population, namely, Dutch, community-dwelling elderly with an increased risk of falling, aged 70 and over. It consisted of questions on activities of health professionals such as detection of fall risk, falls prevention programs, stimulating participation, and financing falls prevention. Open questions, multiple choice questions and questions with 5-point Likert scales were used. In general, Likert scales ranged from 'least' (1) to 'most' (5). After two weeks and, when necessary, three reminders, the first round responses were summarised and the collective opinion of the panel was used in order to develop questions for the second round. A second round made it possible to still reach consensus on some questions. The second round questionnaire again contained a general introduction on the studied population and consisted of open questions, multiple choice questions, and questions with 5-point Likert scales. After two weeks and, when necessary, three reminders, the responses were summarised. The level of consensus between the experts was determined at the end of the second round. The results of both the first and second round were used to write this manuscript.

2.4 Data analysis

Those health experts that completed the first or second round questionnaire were included in this study. The median and Inter Quartile Deviation (IQD) were reported for questions with 5-point Likert scales. The median represents the 'middle' number, whereas the IQD shows to what extent the answers of the experts were similar, that is, if consensus was reached. An IQD lower or equal to 1 was considered as consensus. Frequencies were reported for the other questions. A frequency higher or equal to 75% was considered as consensus. SPSS version 21 was used to analyse the data in the first and second round. This study was executed using open-source LimeSurvey software [20].

3. Results

A total of 125 health experts in the field of falls prevention were recruited in this Delphi study. Respectively 68% (n = 85/125) and 58% (n = 72/125) of the entire panel of health experts filled in the first and second round questionnaires completely. Both questionnaires were filled in completely by 50% (n = 63/125) of the panel. The panel consisted mainly of health experts working in the community (n = 60/85; 71%) with community physiotherapists (n = 23/85; 27%) and community nurses (n = 9/85; 11%) as largest subgroups. Part of the panel had an unknown occupation (n = 18/85; 21%).

3.1 Detection of fall risk

According to the panel, regular detection of fall risk of community-dwelling elderly with an increased risk of falling hardly takes place (median = 2 [hardly]; IQD = 1). The panel reported several pitfalls in detection of fall risk (Table 1). The most important pitfall was to reach community-dwelling elderly that are not in touch with health professionals (median = 5 [very important]; IQD = 1). When detection of fall risk does take place, it mostly happens by mapping the fall history (n = 67/85; 79%). A wide range of answers was given on the question how much time is spent on detection of fall risk annually. Namely, 'less than fifteen minutes' (n = 9/72; 13%) and 'more than sixty minutes' (n = 9/72; 13%) were most often indicated. Although regular detection of fall risk hardly takes place, 60% (n = 49/81) of the panel reported that detection of fall risk should take place annually. Several success factors in detecting elderly with an increased risk of falling were reported by the panel (Table 2). Involving informal caregivers was considered to be the most important success factor (median = 5 [very important]; IQD = 1). The panel was asked to indicate which health professionals should particularly be involved in detection of fall risk. The general practitioner (n = 43/72; 60%) and home care worker (n = 34/72; 47%) were most often indicated. The panel indicated that elderly are reluctant (median = 3 [reluctant]; IQD = 1) to participate in the annual detection of fall risk. In order to increase the participation rate, more awareness on the benefits of prevention should be realised.

Table 1. Pitfalls in detecting community-dwelling elderly with an increased risk of falling.

Pitfall	Median	IQD
Community-dwelling elderly: not in touch with health professionals	5*	1
Elderly are embarrassed	4†	1
Elderly recognise the benefit of prevention only after a fall	4†	1
Cognitive limitations of the elderly	4†	1
Family of the elderly have insufficient knowledge concerning detection of fall risk	4†	1
Falling is not recognised as preventable, part of life	4†	1
Unknown risk factors of falling	4†	1
No proper detection	4†	1
Other competing health problems	4†	1
Inadequate communication with other health professionals	4†	1
Health professionals only respond after a fall	4†	1
Insufficient systematics in detection of fall risk	4†	1
High workload of healthcare professionals	4†	1

* = very important; † = important.

Table 2. Success factors in detecting community-dwelling elderly with an increased risk of falling.

Success factor	Median	IQD
Involving informal caregivers	5*	1
Better cooperation with the general practitioner	4†	1
More awareness for the patients at risk	4†	1
Walk-in hours for falls prevention	4†	1
Emphasising the importance of detection of fall risk	4†	1
Good communication with care partners	4†	1
National health education about prevention	4†	1
Cooperation with chain partners	4†	1
More contact with the target group	4†	1
More health education for the elderly	4†	1
More home visits	4†	1
Use of a practise nurse specialised in ‘frail elderly’	4†	1

* = very important; † = important.

3.2 Falls prevention programs

According to 73% of the panel (n = 37/51), 0–40% of the elderly with an increased risk of falling are referred to exercise programs. The exercise programs that are offered most often according to our panel are 'In Balans' (n = 37/85; 44%), 'Wandelprogramma' (n = 29/85; 34%), 'Vallen Verleden Tijd' (n = 14/85; 16%), and 'Otago' (n = 13/85; 15%). A description of these exercise programs is provided in Supplementary Text S1. The panel was asked how best to offer exercise programs in general. The programs should be offered by a professional, within a group (n = 45/67; 67%), for at least twelve weeks (n = 31/65; 48%), and once or twice a week (n = 33/65; 51%). Physiotherapists have the most important role in offering exercise programs (n = 59/72; 82%). Apart from exercise programs, the panel examined several other falls prevention programs that where based on international guidelines [8]. These include medication monitoring, vision control and correction, mapping fall risks in and around the house, and screening for and supplementation of vitamin D. The panel considers medication monitoring (median = 5 [very]; IQD = 1), vision control and correction (median = 5 [very]; IQD = 1), and mapping fall risks in and around the house (median = 5 [very]; IQD = 1) as very effective programs. On the contrary, no consensus was reached on the effectiveness of screening for and the supplementation of vitamin D (median = 4 [reasonably]; IQD = 2). The panel was asked which health professionals should be responsible for these specific programs. Consensus was reached on the general practitioner (n = 62/72; 86%), being responsible for medication monitoring, and the occupational therapist, being responsible for mapping fall risks in and around the house (n = 54/72; 75%). According to the panel, the optometrist (n = 47/72; 65%) should be involved in vision control and correction, and the general practitioner (n = 54/72; 75%) should be involved in screening for and supplementation of vitamin D.

3.3 Follow-up

Structural follow-up is often lacking. Namely, according to the panel, one month (n = 21/43; 49%), three months (n = 24/42; 57%), and six months (n = 27/45; 60%) after an exercise program, follow-up is never or hardly ever offered. Reasons for not offering follow-up were, amongst others, a lack of time and priority, and a lack of financial compensation. According to the panel, particularly physiotherapists (n = 29/72; 40%) should be involved in offering follow-up.

3.4 Stimulating participation

According to 56% (n = 26/46) of the panel, 0–40% of the elderly with an increased risk of falling are willing to participate in falls prevention exercise programs. The most important obstacle for elderly to participate in falls prevention programs is the lack of motivation (n = 17/62; 27%). Maintaining independence is the most important positive incentive to participate (n = 19/66, 29%). According to 40% (n = 16/40) of the panel, less than ten minutes per elderly are spent on stimulating participation in their institution, annually. The panel was presented with three methods of stimulating participation, namely, national health education, healthcare counselling, and removal of financial barriers. The panel was then asked to estimate the percentage of participation when a specific method of stimulation – or a combination of all methods – will be applied. When a combination of all methods will be applied, the majority of the panel (n = 47/64; 73%) assumes that 41–80% of the elderly with an increased risk of falling would participate in falls prevention programs (Figure 1). According to the panel, health professionals that should particularly be involved in stimulating program participation are the general practitioner (n = 51/72; 71%) and the informal caregiver (n = 33/72; 46%).

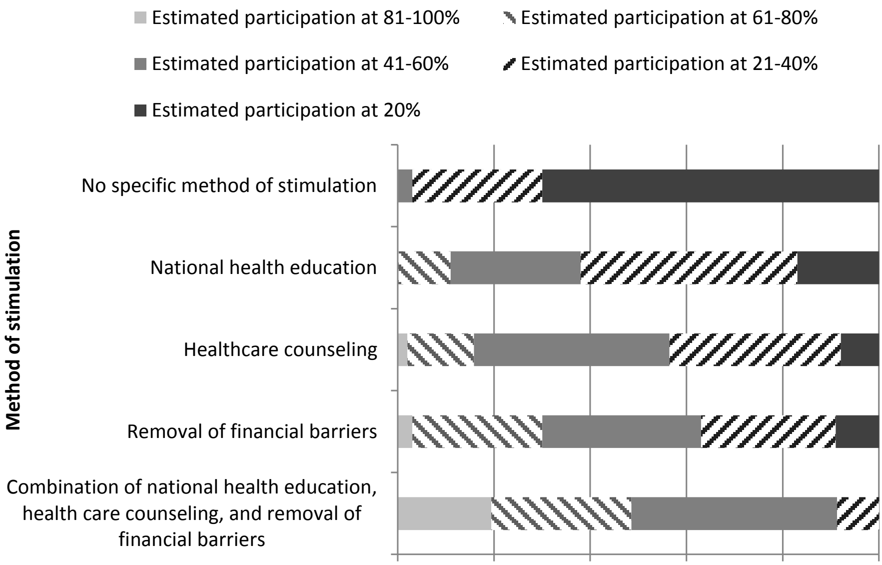

Figure 1. Estimated percentage of participation per method of stimulation.

3.5 Financing falls prevention

The panel was asked how falls prevention should be financed. Financing falls prevention through private health insurance (n = 21/61; 34%) was indicated the most. Full financing by elderly was not indicated by any of the panel members (n = 0/61; 0%).

4. Discussion

To our knowledge, this is the first Delphi study focusing on the current falls prevention activities in community-dwelling elderly with an increased risk of falling at country level. With this Delphi study we aimed to determine how elderly with an increased risk of falling are detected, which falls prevention activities are used and why, how elderly can be stimulated to participate, and how to finance falls prevention. Our Delphi study showed that, in the Netherlands, there is considerable room for improvement in these areas. Namely, it was shown that regular detection of fall risk of elderly with an increased risk of falling is rare, referral to falls prevention programs is lacking, and structural follow-up is never or hardly ever offered. Additionally, the majority of elderly are reluctant to participate in falls prevention activities themselves. A study by Jones et al. (2011) stated that health professionals only detect fall risk if elderly express a concern of falling themselves [10]. This could explain the current lack of regular detection of fall risk of elderly with an increased risk of falling. The health professionals included in our Delphi study did recommend detection of fall risk, as suggested by others [21, 22]. In our Delphi study it seems that, in order to implement better detection of fall risk in the current healthcare system, the general practitioner and informal caregiver should take on more active roles. Furthermore, our Delphi panel mentioned stimulating program participation as a role for these individuals as well. Allocating such roles to a health professional and informal caregiver has been mentioned by others, as well [9, 21-23]. The lack of referring elderly with an increased risk of falling to falls prevention programs could be explained by the fact that health professionals often lack the time and expertise to give elderly proper falls prevention advice [10]. Other studies have identified similar areas crucial to stimulating participation in falls prevention programs as we found. Specifically, Dickinson et al. (2011) showed that participation rates will increase when sufficient information about the content of falls prevention is offered to the elderly [24]. Furthermore, Franco et al. (2015) showed that removal of financial barriers is desired by the elderly [14]. This corresponds to our Delphi study, since the panel indicated that, by providing a combination of national health education, healthcare counselling, and removal of financial barriers, the participation rate of elderly in falls prevention programs is assumed to increase. In terms of the content of falls prevention programs, several topics have been identified in our study. First, it was stated that exercise programs are best offered by a professional, within a group, for a least twelve weeks, once or twice a week. In practise, the physiotherapist will be considered key in offering these exercise programs and follow-up, as has been suggested by previous research [7]. Second, medication monitoring, vision control and correction, and mapping fall risks in and around the house were regarded by the panel as very effective falls prevention programs. No consensus was reached on the effectiveness of screening for and supplementation of vitamin D. A review of meta-analyses conducted by Stubbs et al. (2015) showed similar results, as the effectiveness of vitamin D supplementation was inconsistent in this study [7]. The results of this study will mainly be useful in developing and supporting successful falls prevention programs in the Netherlands. It is difficult to generalise the findings of this study to other parts of the world, mainly due to the differences in healthcare systems. However, falls in the elderly are a worldwide problem [25], and low participation rates in falls prevention programs are universally found [11, 12]. International data on how to improve participation rates in practice are scarce. Local studies can provide valuable insights for a broad international audience, since besides local context factors, potential generic factors can also be identified. For example, most pitfalls and success factors in the detection of fall risks, that were identified by our panel, could play an important role in other countries as well.

4.1 Limitations and strengths

A limitation of our Delphi study is the fact that formal guidelines on conducting a Delphi study are lacking [17, 18]. On the other hand, a Delphi study does yield credible expert opinions [18], which can eventually lead to discussions at a local, national, and global level [19]. In our Delphi study, there was an unequal distribution of professionals, as a large group of community physiotherapists and a small group of general practitioners participated. This may have resulted in an overestimation of the perceptions of community physiotherapists, although this distribution is indicative of the degree to which the different professional groups are actively involved in falls prevention. A total of 125 experts in the field of falls prevention were recruited for our Delphi study, which is much more than the target size of 10–18, as suggested by Okoli & Pawlowski (2004) [26]. A larger panel improves the reliability of the study [18]. As brought forward by our Delphi study, there are many factors contributing to the effectiveness of falls prevention activities. However, future implementation research is needed in order to clearly determine which factors are most important [9, 27].

5. Conclusion

Our Delphi study showed clear directions for improving falls prevention activities and how to increase participation rates. The lack of detection of fall risk, referral to falls prevention programs, structural follow-up, and stimulating participation indicate considerable room for improvement. One suggestion is to annually detect fall risk of elderly aged 70 and over. This can be performed by the general practitioner or community nurse. If the assessment shows that an elderly has an increased risk of falling, an appointment together with the general practitioner and perhaps the informal caregiver can be made. Subsequently, the elderly can be referred by the general practitioner to participate in an exercise program. Furthermore, when necessary, medication can be monitored, vision can be controlled, and fall risks in and around the house can be mapped. If no increased risk of falling is present, detection of fall risk can be repeated the following year.

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7. Supplementary material

Supplementary Text S1. A description of several exercise programs.

In Balans

'In Balans' (In Balance) is a group program, consisting of information sessions and an exercise program. The aim of the program is to prevent falls in the elderly population, by increasing awareness of risk factors and improving balance, mobility, physical fitness, and self-confidence.

Wandelprogramma

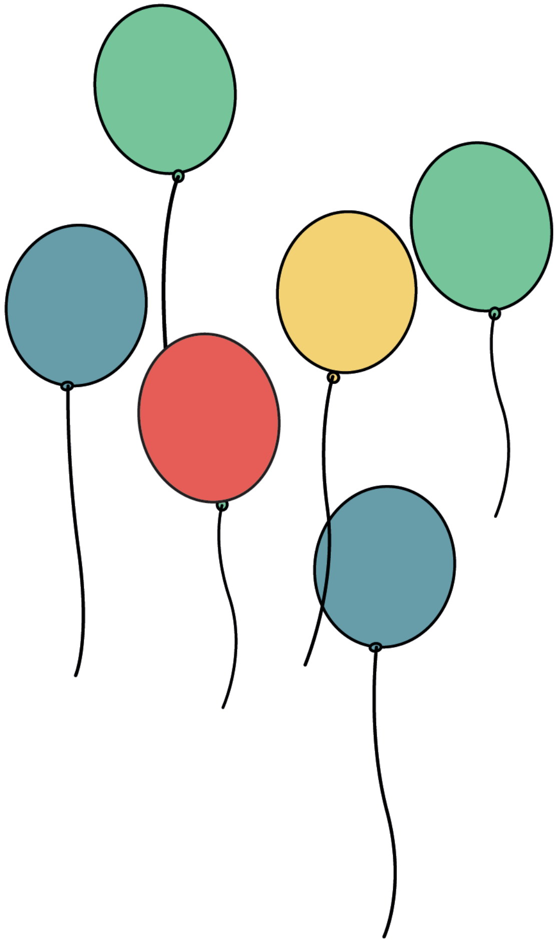
'Wandelprogramma' (Walking program) is a group program, often organised by elderly themselves. Although the program is not specifically aimed to reduce falls, it is based on remaining physically active.

Vallen Verleden Tijd

'Vallen Verleden Tijd' (Falls in the Past) is a group training program, which consists of three aspects, namely, an obstacle course, sports and games, and learning fall techniques. The aim of the program is to reduce the amount of fall incidents in community-dwelling elderly with an increased risk of falling. It is based on mobility problems, fall history, and fear of falling.

Otago

'Otago' is an at-home exercise program tailored to the individual. It can also be offered as a group training program. The program consists of a series of leg and balance exercises, and a walking program. The aim is to prevent falls in the elderly population, by improving muscle strength and balance.



CHAPTER 6

Evaluation of implementing a home-based fall prevention program among community-dwelling older adults

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Abstract

We aimed to describe and evaluate the implementation of a home-based exercise program among community-dwelling adults aged ≥65 years. In an observational study, the twelve-week program was implemented in a community setting. The implementation plan consisted of dialogues with healthcare professionals and older adults, development of an implementation protocol, recruitment of participants, program implementation, and implementation evaluation. The dialogues consisted of a Delphi survey among healthcare professionals, and of individual and group meetings among older adults. The implementation of the program was evaluated using the framework model RE-AIM. In the dialogues with healthcare professionals and older adults, it was found that negative consequences of a fall and positive effects of preventing a fall should be emphasized to older adults, in order to get them engaged in falls prevention activities. A total of 450 older adults enrolled in the study, of which 238 started the program. The process evaluation showed that the majority of older adults were recruited by a community nurse. Also, a good collaboration between the research team and the local primary healthcare providers was accomplished, which was important in the recruitment. Future falls prevention studies may use this information in order to translate an intervention in a research project into a community-based program.

1. Introduction

Fall-related injuries among older adults are recognized as a large burden to Western society [1], which is expected to increase, due to the ageing population. If the yearly increase of fall-related emergency department (ED) visits in the United States remains the same until 2030, the number of visits is expected to increase by 137%, to 5.7 million [2]. These increasing ED visits have a major impact on healthcare costs [3]. The impact of falls does not relate only to ED visits, but also to minor injuries treated at a general practitioner. Furthermore, falls have a large impact on the lives of older adults, as it can result in functional decline and loss of autonomy [4]. Many falls prevention programs have proven to be effective in reducing falls among older adults [5-9]. This mainly concerns multifactorial programs, which include an exercise component [5-9]. Furthermore, single exercise interventions have been proven to be effective in a community setting [7]. Effective group-based exercise programs are often offered on location, whereas older adults seem to favour individual-based programs offered in their homes [10]. This preference could be explained by the fact that group-based programs are generally more expensive, with less good accessibility [11]. Despite the existence of evidence-based programs, the successful implementation of falls prevention in the community remains a complex challenge [12]. There are only few studies that have evaluated the implementation of a falls prevention program. The majority of papers have focused on implementing falls prevention in a clinical setting [13-16]. Other studies have focused on the implementation of group-based exercise programs in the community [17-19]. To our knowledge, no study has evaluated the implementation of a home-based exercise program in the community. A review that evaluated five meta-analyses showed that effective implementation of a prevention program is strongly associated with better health-related outcomes [20]. Thus, evaluation of our implementation program could be helpful for effectively translating an intervention in a research project into successful community-based programs. The comprehensive evaluation framework model RE-AIM has been often used to evaluate implementation studies [21]. This model consists of five dimensions: reach, effectiveness, adoption, implementation, and maintenance. The aim of this paper was to describe and evaluate the implementation of a home-based exercise program in a community setting, among adults aged ≥65 years. Except for effectiveness, this paper describes the measures relating to the RE-AIM model.

2. Materials and methods

2.1 Study design and population

In the current observational study, a home-based exercise program was offered for twelve weeks to community-dwelling adults aged ≥65 years, living in the city of Breda, in the Netherlands. Older adults that did not understand the Dutch language, those with dementia, or those living in a residential care facility, were excluded. The implementation of the home-based exercise program consisted of multiple steps, which will subsequently be discussed (Figure 1). Written informed consent was provided by all participants. The medical ethics committee of Erasmus MC, University Medical Center Rotterdam, waived ethical approval of the study (number 2017-139).

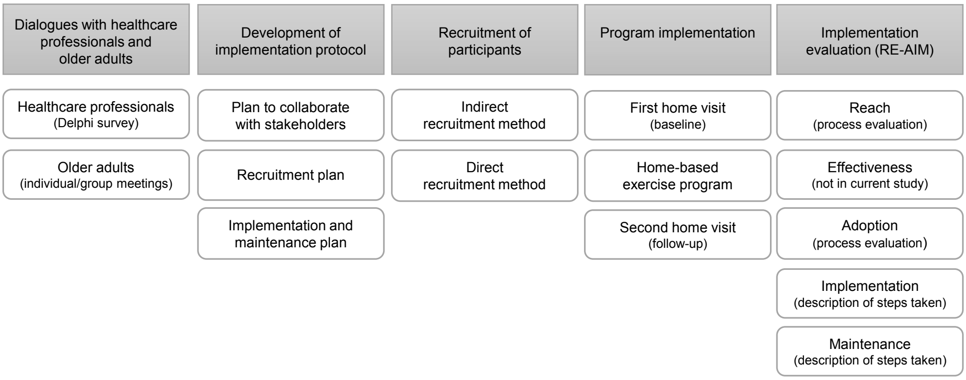

Figure 1. Steps taken to implement a home-based exercise program.

2.2 Dialogues with healthcare professionals and older adults

Prior to the implementation phase, dialogues with healthcare professionals and older adults were performed. The aim of the dialogues was to develop strategies to implement a falls prevention program in a community setting, taking into account the local needs and infrastructure. These strategies were determined based on a Delphi survey that was performed among a panel of healthcare professionals, and based on individual and group meetings that were organized among a user panel of older adults. The measures of this twofold approach were used to develop the implementation protocol.

2.2.1 Healthcare professionals

A panel of healthcare professionals was consulted in a Delphi survey, consisting of two rounds of online questionnaires. This study was based on a previously published Delphi study [22]; however, questions were adjusted to the local settings of Breda and to the program that would be implemented. The Delphi panel consisted of community nurses, physiotherapists, occupational therapists, general practitioners (GPs), and geriatricians, from all over the Netherlands. The healthcare professionals were recruited through purposive expert sampling, in which the research groups' personal network, the network of healthcare professionals, and websites on falls prevention were used. After the first questionnaire was completed by the panel, responses were summarised in order to develop a second questionnaire. This made it possible to elaborate on all topics. The questionnaires consisted of multiple choice and ranking questions. In the current manuscript, multiple choice data is reported as number and percentage, whereas data on ranking is reported as rank (i.e., 'most' (1) to 'least' (5 or 6)) and percentage. The level of consensus among the panel was considered as a frequency of ≥75% on multiple choice or ranking questions. The answers of healthcare professionals that completed the second round questionnaire were included in the data analysis, and are discussed in this manuscript. The online questionnaires were conducted using open-source LimeSurvey software [23]. Analyses were performed using SPSS Statistical Data software (IBM), version 24 (BO: International Business Machines Corporation (IBM), New York, United States).

2.2.2 Older adults

A user panel of community-dwelling adults aged ≥65 years, living in Breda, was consulted in individual and group meetings. The user panel was recruited by local community nurses. Initially, all members of the user panel were asked to participate in a group meeting. However, as some individuals had trouble walking, those individuals were visited at home, by a member of the research team. The group meetings took place in community centres, located near the homes of the older adults, and were led by a member of the research team. Another member of the research team was present to take notes during the group meetings. The questions of the individual and group meetings were drafted together with another panel of older adults, in a participatory design approach. This user panel consisted of older adults that were part of an 'older adult forum', which aims to improve the quality of life and care of older adults. The topics that were discussed during the individual and group meetings were about the barriers and facilitators for participating in falls prevention activities, and about the individuals considered key in falls prevention. The notes that were taken during the meetings by a member of the research team were used to identify and cluster specific themes. These themes were summarized, which are reported descriptively in the current paper.

2.3 Development of implementation protocol

The implementation protocol consisted of multiple topics such as a plan on the structural collaboration with stakeholders and a recruitment plan to determine which methods should be used to recruit the study population. Furthermore, a plan for practical implementation and maintenance of the program was included, which consisted of the steps taken to embed tasks concerning the implementation of the program in local organizations. During the study period, the protocol was revised and adjusted when necessary.

2.4 Recruitment of participants

The recruitment of participants consisted of indirect and direct methods. Indirectly, older adults were recruited for the study by a press release, advertisements in local papers, and commercials broadcasted on a local television and radio channel. Word of mouth resulted in older adults being recruited, as well. Directly, older adults were recruited with a personal approach by primary healthcare providers, such as community nurses, physiotherapists, occupational therapists, and GPs. Also, information sessions and workshops for older adults were held by the research team in community centres, and flyers about the study were distributed at senior living apartments and in shopping malls. As reported previously, older adults with dementia were excluded from participating. All primary healthcare providers that were involved in the recruitment of older adults were informed about this exclusion criteria. By informing these stakeholders, an attempt was made to minimize the chances of an older adult with dementia enrolling. In the current paper, a distinction is made between older adults that 'enrolled' and 'participated' in the study. The number of older adults that 'enrolled' in the study corresponds to the number of applications that were received by the research team by telephone, regular mail, or email. The number of older adults that 'participated' in the study corresponds to the number of individuals that started the twelve-week home-based exercise program.

2.5 Program implementation

All participants were offered a home-based exercise program, which was based on the Senior Step intervention [24]. In the Senior Step intervention, participants performed self-tests for assessing mobility and fall risk. The safety and feasibility of these tests were evaluated in that study. Apart from the self-tests, participants were also offered an instruction book with exercises. The instruction book was developed by two physiotherapists, and was based on the Otago program [25]. The book consists of exercises to: (1) promote safe use of walking aids, (2) improve mobility (e.g., standing up from a chair), (3) improve reaching (i.e., forwards, sideways, and backwards), (4) improve quality of walking and walking speed, and (5) improve overall fitness (i.e., agility, strength, balance, and conditioning). The book is divided into four levels, ranging from simple, low intensive to complex, intensive exercises. In the current study, the instruction book of the Senior Step intervention was offered to participants as a home-based exercise program, for twelve weeks. During a first home visit at baseline, a member of the research team offered and explained the instruction book to the participant. The participant was advised by the research team on the exercise 'level' to start with, based on their mobility. Though, during the study period, the participant could themselves change the type and duration of exercises. During the first home visit at baseline, an 'assessing care of vulnerable elders' (ACOVE) questionnaire was given to the participant. This questionnaire evaluated the provided healthcare after a fall, in the previous 12 months [26]. It was used to create a baseline situation of the local fall-related healthcare. After twelve weeks of follow-up, a second home visit with a member of the research team took place. During this home visit, the instruction book was returned to the research team and the exercise program was evaluated with the participant by a questionnaire.

2.6 Implementation evaluation

In order to describe and evaluate the implementation of the home-based exercise program, the comprehensive framework model RE-AIM was used. This model consists of the dimensions of reach, effectiveness, adoption, implementation, and maintenance [21]. In general, by evaluating the different dimensions within a study, information regarding the translation of research to practice is gained [21]. The original RE-AIM dimension definitions and the definitions used in the current study are presented in Table 1. The dimension 'reach' was assessed through process evaluation, as the proportion of older adults enrolled in the study through indirect and direct methods. This information was gathered by asking every older adult that enrolled in the study how they were recruited. The barriers and facilitators in recruiting participants were also described for this dimension. The dimension 'effectiveness' is not discussed, as it was not the focus of the current paper. More information about the effectiveness of the program can be found in an earlier paper about the study [27]. The main findings of that paper were that 52% of the participants indicated that they frequently took part, which means that the exercises given in the instruction book were performed daily or a few days per week during the study period. Furthermore, the analyses indicated that a higher degree of pain was associated with frequent participation; however, frequent participation resulted in better health perceptions, over time. The activities that were executed to optimize collaboration between the research team and different local stakeholders were described within the dimension 'adoption'. 'Implementation' was assessed through a process evaluation, as it was defined by the extent to which the twelve-week program was realized as planned. Also, program satisfaction of the participants was reported. As described in the previous paragraph, this information was based on a questionnaire that was administered after twelve weeks of follow-up. Questions included how much the participants liked the program; how useful they evaluated it to be; and whether the participants noticed a change in their risk awareness, confidence in balance, and in their level of physical activity during the study period. The number (n) and percentage (%) are reported for these measures, and the analyses were performed using SPSS Statistical Data software (IBM), version 24. Lastly, in order to evaluate the maintenance of the program, a description was given of the steps taken to embed the tasks concerning the implementation of the program in local organizations.

Table 1. Original definitions of RE-AIM dimensions: reach, adoption, implementation, and maintenance [21], and definitions of current study.

Dimension	Original definition	Study definition
Reach	Proportion of individuals that participated in the program	Proportion of individuals that enrolled in the study through indirect and direct methods; barriers and facilitators in recruitment
Effectiveness	Outcome effects of implementing the program as planned	Not discussed in current manuscript
Adoption	Proportion of practices and individuals that adopted the program	Activities executed to optimize collaboration with stakeholders
Implementation	Extent to which the program is implemented as planned	Extent to which the program was implemented as planned; program satisfaction of the participants
Maintenance	Extent to which a program is maintained over time	Activities executed to maintain the program locally

3. Results

The implementation plan components 'dialogues with healthcare professionals and older adults', 'program implementation', and 'implementation evaluation' will subsequently be discussed in the results section (Figure 1).

3.1 Dialogues with healthcare professionals and older adults

3.1.1 Healthcare professionals

A total of 129 healthcare professionals participated in the Delphi survey. The first questionnaire was completed by 81% (n = 105/129) of the panel, whereas the second questionnaires was completed by 74% (n = 95/129). According to the panel, the most important barrier in organizing falls prevention in a community setting is reaching older adults that are not in touch with healthcare professionals (n = 55/95; 58%) (Table 2). Poor communication between different stakeholders (n = 50/95; 53%) and absence of a coordinator (n = 49/95; 52%) were mentioned as barriers, as well. Important facilitators in organizing falls prevention in a community setting are good cooperation between different healthcare professionals (n = 57/95; 60%) and taking into account the wishes and needs of older adults (n = 57/95; 60%) (Table 2). The panel was also asked which individuals were considered key in organizing falls prevention in a community setting. A neighbourhood care team (n = 26/95; 27%), the physiotherapist (n = 23/95; 24%), and the community nurse (n = 22/95; 23%) were most mentioned. A perceived barrier for participating in a falls prevention program was that older adults are not aware of the possibilities in their neighbourhood (n = 32/93; 34% (rank 1)). Consensus was reached on facilitators to increase participation. Namely, emphasizing to older adults that falls prevention is important in maintaining functional independence was mentioned by 77% of the panel (n = 72/94; (rank 1)). Furthermore, an effective measure to increase participation rates among older adults is to raise awareness on the consequences of a fall (n = 43/94; 46% (rank 1)). Both the GP (n = 32/94; 34% (rank 1)) and the informal caregiver (n = 28/94; 30% (rank 1)) were considered key individuals in stimulating participation among older adults.

Table 2. Barriers and facilitators according to healthcare professionals (n=95) in organizing falls prevention in a community setting.

Barrier	**(%)**
Reaching older adults that are not in touch with healthcare professionals	58
Poor communication between different stakeholders	53
Absence of a neighbourhood coordinator	52
Healthcare professionals that do not have enough knowledge on falls prevention	47
High costs	36
Lack of time	31
Lack of a central location in a large neighbourhood	15
Facilitator	**(%)**
Good cooperation between different healthcare professionals	60
Taking into account the wishes and needs of older adults	60
Clear communication between different stakeholders	48
Shared vision on falls prevention in a community setting among stakeholders	42
Word of mouth	31
Providing good information about falls prevention to healthcare professionals	28
Neighbourhood coordinator that takes control	21

3.1.2 Older adults

In total, three individual and four group meetings with user panel members took place among a total of 27 older adults living in Breda. Three individual meetings took place in the homes of older adults, whereas four group meetings took place in community centres among 24 older adults. In every group meeting, four to eight older adults were present. Several barriers of participating in falls prevention activities were identified by the older adults during these meetings. Chronic pain, fear of participating, program costs, poor accessibility, and unawareness of their own fall risk were most often mentioned. Increasing awareness of the personal relevance of falls prevention was identified as an important facilitator. The user panel mentioned that their awareness increased after they had fallen. In order to raise awareness and increase participation rates among other older adults, the panel suggested emphasis on the negative consequences of a fall. Also, the positive effects of preventing a fall, such as maintaining functional independence, should be stressed upon. Furthermore, according to the user panel members, it was considered important to offer advice (and not frighten) to older adults concerning falls prevention activities. This way, they can make a deliberate choice without feeling forced to do so. Another strategy considered effective in engaging older adults in falls prevention activities is by involving a trusted individual, such as the community nurse, informal caregiver, or neighbour. Such an individual was thought to be different for every older adult, but was perceived to be of help in stimulating participation.

3.2 Program implementation

A total of 450 older adults enrolled in the study, of which 238 older adults started the twelve-week home-based exercise program. Additional information on the baseline characteristics of older adults that enrolled the study, but did not participate, is provided in Supplementary Table S1. At baseline, 52% (n = 124/238) of the participants were reported to have had a fall in the past twelve months. Out of these participants, 59 participants reported that they had visited a GP or an Emergency Department following the fall. In 12% of these 59 participants, an eye exam was performed, 15% was given a memory test, 25% was given a balance test, 22% was given advice about safety in and around the house, and 22% of the participants was advised by their physicians to start an exercise program. These results show that a limited number of participants were offered specific care to prevent a subsequent fall, prior to the implementation of the exercise program in their community.

3.3 Implementation evaluation

3.3.1 Reach

Indirect and direct methods

The indirect recruitment methods potentially reached 122,000 older adults. The majority of these older adults (n = 70,000) were reached through press releases about the study. Directly, over 3100 older adults were potentially reached. Recruitment through a community nurse (n = 1220) and through flyers about the study (n = 1000) resulted in the majority of these older adults being reached. As reported in the Methods section, every older adult that enrolled in the study was asked how they were recruited. A total of 450 older adults enrolled in the study, of which 290 indicated the method of their recruitment. Twelve older adults indicated to have been recruited through an indirect method and 278 older adults through a direct method. Of the individuals recruited through a direct method, the majority (n = 233) were recruited through a community nurse.

Barriers and facilitators

Firstly, a barrier in recruiting participants was that, although several older adults were contacted, relatively few enrolled in the study. Indirect methods, particularly, resulted in a small number of older adults being enrolled in the study. Secondly, even though many local GPs were asked to be involved in the recruitment of study participants, not many were active in doing so. An exception being that by contacting practice nurses with specialization in care for older adults, it was possible to involve a few local GPs in the recruitment of study participants. Third, collaboration with the local government was difficult. Reasons for the local government not being involved in the study was because falls prevention was not high on their agenda, and there also was a lack of budget. One recruitment method was identified as a facilitator in recruiting participants—personal approach by a community nurse encouraged older adults to engage in falls prevention activities, which resulted in the majority of enrolments. Another identified facilitator was the huge support for implementation of the program by local, primary healthcare providers. Optimizing a collaboration between the research team and these healthcare professionals was important in reaching and recruiting older adults.

3.3.2 Adoption

Several activities were executed to optimize collaboration between the research team and local stakeholders, and facilitate adoption of the program. At the start of the study, neighbourhood profiles were developed, which consisted of information on age distribution and socio-economic status of the inhabitants, and of a list of stakeholders we could potentially collaborate with. Then, a network with relevant stakeholders in every neighbourhood was set up. This network consisted of, amongst others, local primary healthcare providers (i.e., community nurses, physiotherapists, occupational therapists, GPs, and practice nurses), older adult unions, local initiatives for older adults, and volunteers. The network of stakeholders acted as an advisory body. Namely, during the study period, meetings were organized in order to discuss several topics related to the local implementation of the exercise program. This was particularly related to the recruitment of older adults. Also, the wishes, needs, and expectations of all stakeholders were discussed. In order to keep all stakeholders informed, a quarterly newsletter was sent to them and others interested.

3.3.3 Implementation

Implemented as planned

The twelve-week home-based falls prevention program was, except for two elements, implemented as planned. Two necessary adaptations were made during the program. Originally, adults were recruited in two Breda neighbourhoods. As it became clear that relatively few older adults would enrol in the study, recruitment was extended to a total of eight neighbourhoods. Furthermore, eight participants did not agree to a second home visit after twelve weeks. These participants received a follow-up questionnaire by regular mail instead.

Program satisfaction

A questionnaire on program satisfaction was conducted among the participants that completed the twelve-week program. Fifty-nine percent of the participants said that they moderately or strongly liked the program. The program was evaluated as at least moderately useful by 71% of the participants. Fifty-two percent of the participants agreed or strongly agreed with noticing a change in the awareness of their fall risk during the study period (Figure 2). Forty-three percent agreed or strongly agreed with noticing an increased confidence in their balance, and 37% agreed or strongly agreed with noticing a change in their level of physical activity during the study period.

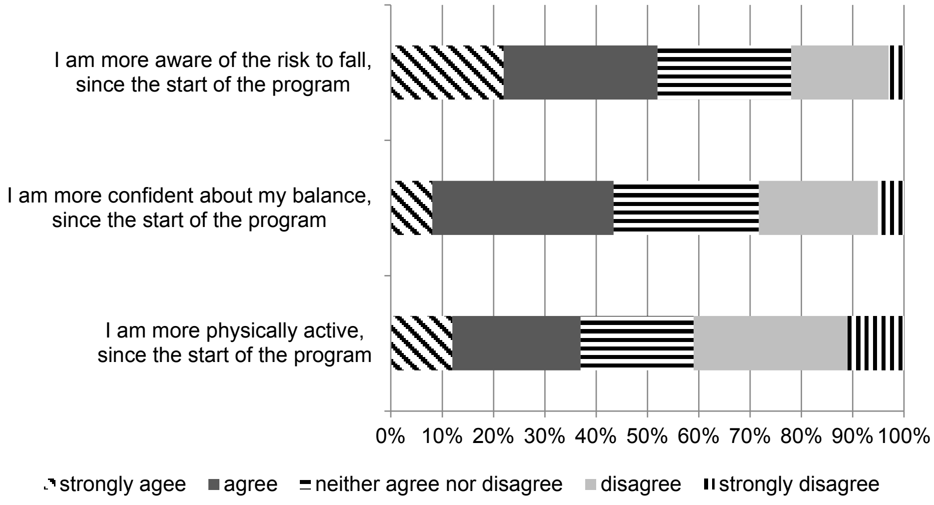

Figure 2. Program satisfaction of the participants after the twelve-week home-based exercise program.

3.3.4 Maintenance

In order to maintain the home-based exercise program locally, an invitational conference was organized after the study period. This conference included all relevant stakeholders, such as older adults living in Breda, the municipality, a health insurer, home care organizations, local initiatives, GP representatives, a hospital, and physical and occupational therapists. During the conference, a presentation was made by the research team on the process and results of implementing the exercise program in the community. A discussion followed, which led to three stakeholders with interest in taking over the responsibilities of structurally implementing and financing the falls prevention program locally.

4. Discussion

The current paper describes and evaluates the implementation of a home-based exercise program among older adults. The dialogues with healthcare professionals and older adults showed that, in order to stimulate participation rates among older adults, the negative consequences of a fall should be emphasized. The positive effects of preventing a fall, such as maintaining functional independence, should be emphasized, as well. According to healthcare professionals and older adults, the informal caregiver is a key individual in stimulating participation among older adults. Using the framework model RE-AIM, the evaluation of implementing the home-based exercise program showed that many older adults were potentially reached, but relatively few enrolled in the study. Personal recruitment by their own community nurse was the most effective method of recruiting older adults. Furthermore, in the recruitment of older adults, a good collaboration between the research team and the local primary healthcare providers was important. As reported previously, the current home-based exercise program was based on the intervention 'Senior Step'. In the evaluation study of this intervention, an information meeting was much more effective in reaching and recruiting participants than a personal approach [28]. This is in contrast to our study, as we did recruit some participants by providing information sessions, but the majority of participants were recruited face-to-face by a community nurse. An explanation for this difference could be that, in the 'Senior Step' study, older adults living in a residential care facility were recruited as well. A study on an integrated neighbourhood approach to support community-dwelling older adults in the Netherlands showed that community engagement is very important in the adoption of a program [29]. Likewise, a study on the implementation of a falls prevention program in the United States reported that having solid community partnerships is

essential for good program adoption by stakeholders [17]. These results correspond to our study, as creating broad support among local stakeholders proved to be important in successfully implementing the program. Keeping stakeholders informed during the study period has been found to be important in the implementation success of a previous falls prevention program, as well [13]. By sending newsletters and by organizing network meetings in our study, we tried to inform stakeholders, as well. The network meetings were important to take the wishes and needs of the local stakeholders of different neighbourhoods into account, in order to properly adopt the program. This relates to a study by Peel et al. (2017), who reported that neighbourhoods differ in many characteristics, so it is important to take into account the needs of the local area, in order to effectively adopt and implement a program [15]. The healthcare professionals of the Delphi survey considered the GP as a key individual in stimulating participation among older adults. However, involving GPs in the recruitment of participants proved to be difficult in our study. A study by Brach et al. (2013) on a home-based exercise program for older adults reported that they recruited GPs by contacting a research network [30]. The involvement of GPs in the recruitment of older adults proved to be beneficial in their study. Perhaps, if we had contacted GPs through a research network, a better collaboration could have been established. Apart from the recruitment of older adults, GPs could also have an important role in the adoption of an intervention. Previous research in the Netherlands has shown that the GP can have a central role in multidisciplinary teams, focused on the care for older adults [31]. The paper identifies several competences that are key for a successful GP role, such as leadership and networking.
A GP role with those competences could be of added value to the adoption of a falls prevention intervention. After twelve weeks of follow-up, relatively low satisfaction of the program was reported by the participants, as 59% said that they liked the program. We have not asked why an individual did or did not like the program; however, a possible explanation for the relatively low satisfaction might be that older adults were missing support during the study period. Even though a member of the research team visited the participant twice at home (i.e., at baseline and after twelve weeks), no contact was made with the participant during the study period. Previous research has shown that support from others is considered important in the promotion and adherence of falls prevention interventions [12].
A strength of our study is that the comprehensive evaluation framework RE-AIM was used in order to evaluate the implementation. An evaluation such as this is valuable in translating research into practice. Also, using the different dimensions makes issues related to implementation more explicit, which is sometimes ignored in a more traditional presentation of results. A limitation of the current study is that processing qualitative data of the individual and group meetings with older adults could have been improved. Even though specific themes that emerged from the meetings were identified and clustered, no rigorous content analysis was performed, as it stretched beyond the scope of this study. This analysis could have yielded much richer insights of the important factors for falls prevention and should certainly be included in future research. Even though many older adults were potentially reached, relatively few enrolled in the study. This low willingness to participate could have resulted in selection bias. Nevertheless, despite not many older adults enrolling in the study, an increase in the awareness of falls prevention could still have been realized among this group. As Russell et al. (2017) have shown, the presence of risk awareness does not necessarily lead to older adults being willing to participate in falls prevention [32]. Another limitation of the study is that no information was available on what type or duration of exercises of the instruction book were performed by the participants. Thus, we were unable to determine what type or duration of exercises may have contributed to the

effectiveness of the program. Participants of the current study might not be representative of a general population of community-dwelling older adults. Specifically, as the majority of older adults were recruited through healthcare professionals, the participants of the current study might be older and more frail than the general older adult population. Furthermore, relatively few participants with a migration background were included in the study. Only 6% of the older adult population of Breda has a migration background [33], but in other Dutch cities, this percentage is generally higher. The fact that individuals not understanding the Dutch language were excluded made it difficult for older adults with a migration background to enrol in our study. Even though ethnic minorities are often underrepresented in health research [34], some studies have shown effective methods to recruit immigrant participants. Namely, by providing bilingual program information, and by facilitating partnerships with community organizations, recruitment of immigrant participants could be improved [35, 36]. Future implementation studies should take into account these methods in the planning of their interventions.

5. Conclusion

This study shows that the negative consequences of a fall and the positive effects of preventing a fall should be emphasized to older adults, in order to get them engaged in falls prevention activities. Furthermore, the importance of a good collaboration between the research team and local primary healthcare providers has been identified. Also, particularly community nurses can successfully help in reaching and recruiting older adults for a falls prevention program. All lessons learned in the current study could help and guide future interventions of research projects to successfully translate into community-based programs. As the population ages and absolute numbers of fall-related injuries keep increasing, implementing successful prevention programs will become more and more important in reducing healthcare costs.

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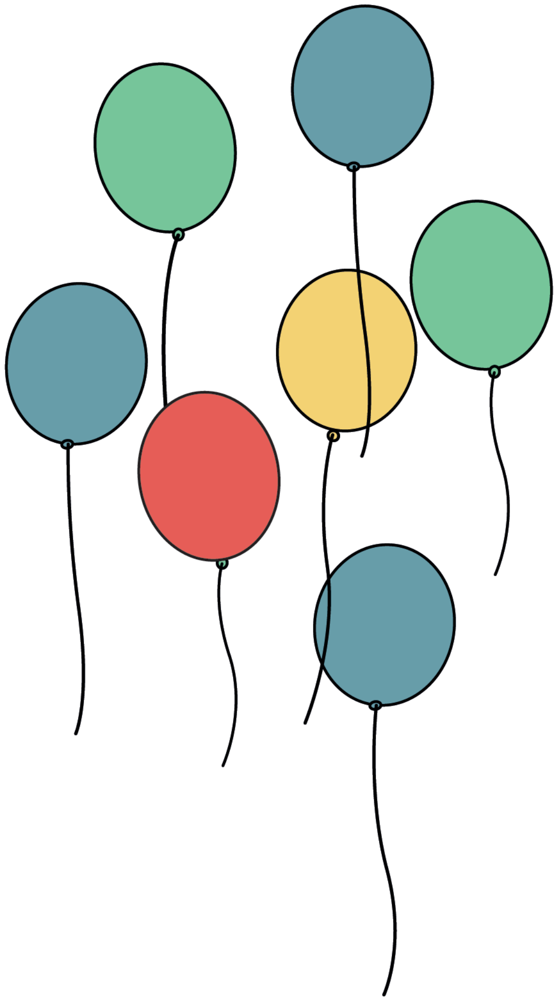
7. Supplementary material

Supplementary Table S1. Baseline characteristics of older adults that applied for the study, but that did not participate.

	Total (n=212)	**No informed consent (n=180)**	**Dropped out before start (n=32)**
	n (%)	n (%)	n (%)
Female	136 (65)[a]	116 (65)[e]	20 (65)[g]
Age - mean ± SD	82.3 ± 8.5[b]	82.2 ± 8.6f	82.7 ± 7.6[g]
Living alone	144 (69)[c]	123 (69)[e]	21 (66)
Elevated fall risk1	26 (81)	n.a.*	26 (81)

SD: Standard deviation; 1: The fall risk test (part of a fall analysis assessment) determined that an elevated fall risk was present when a participant had a fall in the past twelve months, or the participant had mobility problems and a fear of falling [37, 38]; [a]: n=209; b: [n]=195; [c]: n=210; [d]: n=32; [e]: n=178; [f]: n=164; [g]: n=31.



CHAPTER 7

Factors associated with participation of community-dwelling older adults in a home-based falls prevention program

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Abstract

This observational study was conducted to determine which factors are associated with frequent participation in a home-based exercise program. The effects of frequent participation on health-related outcomes over time are investigated, as well. Community-dwelling adults aged ≥65 years participated in a twelve-week home-based exercise program. The program consisted of an instruction book with exercises that were performed individually at home. Frequent participation was classified as performing exercises of the instruction book daily or a few days a week during the study period.
A logistic regression analysis was performed to determine the association between factors (i.e., demographic and health-related characteristics) and frequent participation. Furthermore, to investigate the effects of frequent participation on health-related outcomes, generalized linear and logistic regression models were built. A total of 238 participants (mean age 81.1 years (SD ± 6.7), 71% female) were included in the study. Frequent participation during the study period was indicated by fifty-two percent of participants. Analyses showed that a higher degree of pain (OR: 1.02, 95% CI: 1.–1.04) was associated with frequent participation. In addition, the effect of frequent participation over time was a significant improvement in current health perceptions (B: 4.46, SE: 1.99).

7

1. Introduction

Falls among older adults are a global public health problem, with high levels of healthcare consumption and high costs [1, 2]. In the Netherlands, from the years 2000 to 2017, the population aged ≥65 years increased by 47% to 3.2 million [3]. During that time, fall-related emergency department visits increased by 87% to 124,000 per year [4]. Due to an aging population, the number of falls is expected to further increase in the coming decades. Fortunately, previous studies have shown that prevention programs can reduce falls among community-dwelling older adults [5-8]. The majority of the proven-effective programs consist of an exercise component [5-8]. Even though many exercise programs are offered in a group on location, older adults appear to favour an individual, home-based exercise program [9]. Advantages of a home-based program are good accessibility and lower program costs, as no exercise room or physiotherapist needs to be arranged. The level of participation of older adults in home-based exercise programs is generally low [10]. However, high participation levels may lead to a reduced fall risk [11]. A systematic review and meta-analysis investigated the relationship between program features, level of participation, and the effectiveness of home-based exercise programs [10]. No association was found between level of participation and the effectiveness of a program; however, an association between program features and level of participation was found. Namely, including walking and balance exercise in the program and providing home visit support were associated with a higher level of participation in the program. To our knowledge, no study has investigated the association between participant characteristics, the level of participation, and the effectiveness of a home-based exercise program. This information could help in the planning of future falls prevention interventions. Therefore, the aims of this paper were to: (1) determine which participant characteristics are associated with frequent participation of community-dwelling older adults in a home-based exercise program; and (2) investigate the effects of frequent participation on health-related outcomes over time.

2. Materials and methods

2.1 Study Design and population

In an observational study, community-dwelling adults aged ≥65 years, living in the city of Breda, in the Netherlands, were included in the study. Older adults living in a residential care facility, not understanding the Dutch language, or those with dementia were excluded from participation. All participants were offered a home-based exercise program for twelve weeks. At baseline and after twelve weeks of follow-up, a questionnaire was administered during home visits. Written informed consent was provided by all participants. The medical ethics committee of Erasmus MC, University Medical Center Rotterdam waived ethical approval of the study (number 2017-139).

2.2 Home-based exercise program

The home-based exercise program was based on the Senior Step intervention [12]. In the Senior Step intervention, participants performed self-tests for assessing mobility and fall risk. The safety and feasibility of these tests were evaluated in that study. Apart from the self-tests, participants were also offered an instruction book with exercises. The instruction book was developed by two physiotherapists, and was based on the Otago program [13]. The book consists of exercises to: (1) promote safe use of walking aids, (2) improve mobility, (3) improve reaching (i.e., forwards, sideways, and backwards), (4) improve quality of walking and walking speed, and (5) improve overall fitness (i.e., agility, strength, balance, and conditioning). Amongst others, exercises consisted of walking up and down a slope with a walking aid, standing up from a chair, reaching for a kitchen cupboard, walking a figure eight, or walking up and down the stairs. The book is divided into four levels, ranging from simple, low-intensity to complex, intensive exercises. In the current study, the instruction book of the Senior Step intervention was offered to participants as a home-based exercise program, for twelve weeks. At baseline, a member of the research team visited the participant at home. During this home visit, the researcher gave the participant the instruction book, explained how to use it, and advised the participant about which exercise level would be appropriate for beginning the program. However, during the study period, participants could change which exercises they performed, and how often, without interference from the research team. After twelve weeks of follow-up, a member of the research team called the participant to schedule a second home visit. During this home visit, the instruction book was returned to the research team.

2.3 Recruitment

Between March 2017 and March 2018, participants were recruited through primary care health professionals, such as community nurses, physiotherapists, and general practitioners. Furthermore, information sessions and workshops were held in community centres, advertisements were published in local papers, and commercials were broadcasted on a local television and radio channel. Older adults could apply to participate in the study by telephone, regular mail, or email. When the research team received the application, participants were sent an informed consent form by regular mail. When the research team did not receive a signed informed consent form, the participant was reminded by telephone, regular mail, or email. Participants were called to schedule a first home visit when the research team received a signed informed consent form.

2.4 Outcome variables

2.4.1 Participant characteristics at baseline and follow-up

Data collection took place between July 2017 and June 2018, as baseline home visits were performed between July 2017 and March 2018, and follow-up home visits were performed between October 2017 and June 2018. The baseline and follow-up questionnaire on participant characteristics included demographic characteristics, such as sex, age, living situation (i.e., alone or with someone else), and education. Education was classified as low (i.e., less than primary school, primary school, and little more than primary school), middle (i.e., technical school, vocational education, general secondary/pre-university education), and high (i.e., college/university). Several self-reported measurements were performed, as well. The five-dimensional EuroQol instrument (EQ-5D) and the domain cognition assessed the generic quality of life on the dimensions mobility, self-care, usual activities, pain and discomfort, anxiety and depression, and cognitive function [14]. Mean scores range from 0 (death) to 1 (full health). The fall risk test (part of a fall analysis assessment) determined that an elevated fall risk was present when a participant had a fall in the past twelve months, or the participant had mobility problems and a fear of falling [15, 16]. The Timed "Up & Go" (TUG) measured the mobility, by measuring the time in seconds it took to stand up from a chair, walk three meters back and forth, and sit down again [17]. The Short Falls Efficacy Scale-International (Short FES-I) assessed the concern about falling [18]. The Self-Management Ability Scale Shorter (SMAS-S) determined self-management abilities, which was based on taking initiative, investment behaviour, variety, multifunctionality, self-efficacy, and positive frame of mind [19]. Scores range from 0–100, a higher score means better self-management abilities. The Short-Form General Health Survey of the Medical Outcomes Study (SF-20) measured general health, which was based on physical functioning, role functioning, social functioning, mental health, current health perceptions, and pain [20]. Scores range from 0–100, a higher score means better functioning, and for pain, a higher score means a higher degree of pain.

2.4.2 Level of participation

After twelve weeks of follow-up, participants were asked how often they had performed the exercises outlined in the instruction book. Participants reported that the exercises were performed daily, a few days a week, one day a week, less than one day a week, or not at all. A review by Sherrington et al. (2016) has shown that participating in a falls prevention exercise program, for at least three hours a week, could reduce the fall rate among older adults [6]. We estimated that, in order to reach three hours of exercise, an individual should at least exercise a few days a week. Therefore, we decided to classify an individual who performed exercises daily or a few days a week as having 'frequent participation'. 'Infrequent or nonparticipation' was classified as performing exercises one day a week, less than one day a week, or not at all. The reasons study participants gave for not frequently participating were recorded after twelve weeks as well. As the level of participation is based on self-report, it could have been influenced by social desirability bias. By consistently collecting data in the same way during home visits, an attempt was made to minimize potential bias.

2.5 Statistical analyses

2.5.1 Baseline characteristics

The frequencies of baseline characteristics of all participants were determined. Continuous variables are expressed as mean and standard deviation (SD), and dichotomous variables are expressed as number (n) and percentage (%).

2.5.2 Association between factors and frequent participation

In order to determine the baseline differences between frequent and infrequent or nonparticipating individuals, an independent samples t-test was performed on continuous variables, whereas a Chi-squared test was performed on dichotomous variables. These analyses were performed to determine the baseline differences between completers and dropouts, as well. The association between factors and frequent participation was determined by performing a logistic regression analysis, in which frequent participation was used as a dependent variable. Factors included the baseline demographic characteristics sex, age, living situation, and education. Furthermore, the follow-up health-related outcomes quality of life, fall risk, mobility, fear of falling, self-management, and general health were included. In the univariate logistic regression analysis, the crude association between the factors and frequent participation was calculated. The variables that had a crude association with frequent participation, with a p-value < 0.20, were selected for multivariable model 1. An adjustment for other baseline confounders was performed in multivariable model 2. The confounders of model 2 were selected by investigating the baseline differences between the frequent and infrequent or nonparticipation groups. If a variable differed between the groups with a p-value < 0.20, this variable was selected. Results of the univariate and multivariable analysis are expressed as odds ratio (OR) and 95% confidence interval (CI).

2.5.3 Effects of frequent participation on health-related outcomes

To investigate the effects of frequent participation on health-related outcomes, generalized linear and logistic regression models were built, in which follow-up health-related outcomes were used as a dependent variable. A generalized linear regression analysis was performed on continuous health-related outcomes and a generalized logistic regression analysis was performed on dichotomous health-related outcomes. Health-related outcomes included follow-up quality of life, fall risk, mobility, concern about falling, self-management, and general health. In multivariable model 1, the crude effect of frequent participation on health-related outcomes was adjusted for the baseline variable. An adjustment for the baseline variable and other baseline confounders was performed in multivariable model 2. The confounders of model 2 were selected by investigating the baseline differences between the frequent and infrequent or nonparticipation groups. If a variable differed between the groups with a p-value < 0.20, this variable was selected for multivariable model 2. Results of the logistic regression analysis are expressed as OR and 95% CI, whereas results of the linear regression analyses are expressed as Beta (B) and standard error (SE).

2.5.4 Multicollinearity

To take into account the presence of multicollinearity [21], multiple analyses were performed. The correlations between all independent variables were calculated, and expressed as Pearson correlation coefficients (r). The correlation between two variables is assumed to be low (r = 0.30–0.50), moderate (r = 0.50–0.70), or high (r = 0.70–0.90) [22]. Another way to detect multicollinearity is by calculating a variance inflation factor (VIF). A VIF has been calculated for all independent variables, of which a VIF larger than five or ten is suggested to detect multicollinearity [23]. As baseline and follow-up questionnaires were filled in properly (less than 9% missing data), no imputation measures were considered. A p-value < 0.05 was considered statistically significant. All analyses were performed using SPSS Statistical Data software (IBM), version 24.

3. Results

3.1 Baseline characteristics

A total of 238 adults aged ≥65 years participated in the study, of which 195 participants (82%) completed the twelve-week program (Figure 1). The mean age of all participants was 81.1 years (SD ± 6.7) (Table 1). The majority of participants were women (71%), living alone (63%), with a middle level education (55%), and with an elevated fall risk (69%). No statistically significant baseline differences between completers and dropouts were observed (Supplementary Table S1).

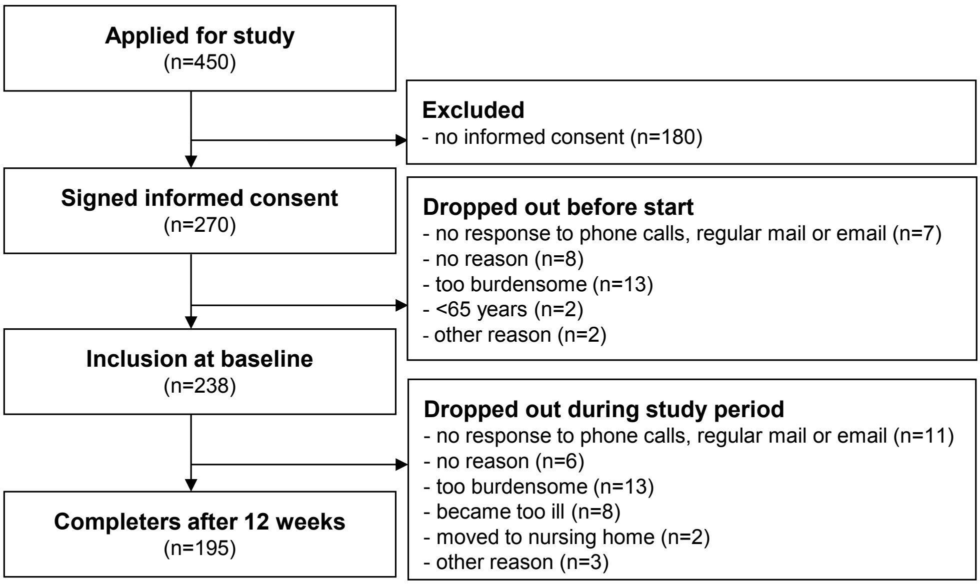

Figure 1. Flowchart of participants in the home-based exercise program.

Table 1. Baseline characteristics, and differences between individuals frequently and infrequently or not participating in the home-based exercise program.

	All participants (n = 238)	Total frequent and infrequent or nonparticipation (n = 195)	Frequent participation (n = 102)	Infrequent or nonparticipation (n = 93)	Difference between frequent and infrequent or nonparticipation*
Demographic characteristics	n (%)	n (%)	n (%)	n (%)	p-value
Female	169 (71)	140 (72)	76 (75)	64 (69)	0.38
Age—mean ± SD	81.1 ± 6.7	80.9 ± 6.6	80.6 ± 6.4	81.3 ± 6.8	0.46
Living alone	151 (63)	124 (64)	66 (65)	58 (62)	0.73
Education					
low	70 (29)	53 (27)	24 (24)	29 (31)	0.23
middle	130 (55)	108 (55)	56 (55)	52 (56)	0.89
high	38 (16)	34 (17)	22 (22)	12 (13)	0.11
Health-related outcomes	mean ± SD	mean ± SD	mean ± SD	mean ± SD	p-value
Quality of life (EQ-5D + cognition)[1]	0.64 ± 0.24	0.65 ± 0.24	0.70 ± 0.23	0.60 ± 0.24	0.00
Elevated fall risk—n (%)	161 (69)[a]	133 (69)[d]	65 (64)[g]	68 (75)[i]	0.12
Mobility (TUG) in seconds	17.0 ± 9.1[b]	16.9 ± 8.9[e]	16.2 ± 7.9[h]	17.6 ± 10.0[j]	0.29
Concern about falling (Short FES-I)	9.8 ± 4.0	9.8 ± 3.9	9.9 ± 3.6	9.7 ± 4.1	0.77
Self-management (SMAS-S)[2]	59.3 ± 16.2[c]	60.1 ± 16.0[f]	63.8 ± 14.9	56.1 ± 16.3[k]	0.00
General health (SF-20)[3]					
physical functioning	45.1 ± 31.7[c]	45.1 ± 31.6[f]	50.2 ± 32.0	39.5 ± 30.2[k]	0.02
role functioning	28.8 ± 41.4	29.2 ± 41.1	34.3 ± 43.9	23.7 ± 37.3	0.07
social functioning	72.5 ± 34.0	74.5 ± 32.7	76.3 ± 32.5	72.5 ± 33.0	0.42
mental health	73.0 ± 20.7[c]	73.2 ± 20.8[f]	74.1 ± 20.8[g]	72.3 ± 20.7	0.55
current health perceptions	46.4 ± 21.1[c]	46.9 ± 21.1[f]	47.1 ± 20.5	46.7 ± 21.9[k]	0.89
pain	33.0 ± 27.6	31.9 ± 27.8	35.8 ± 27.1	27.7 ± 27.9	0.04

SD: Standard deviation; [1]: Mean scores range from 0 (death) to 1 (full health); [2]: Scores range from 0–100, a higher score means better self-management abilities; [3]: Scores range from 0–100, a higher score means better functioning, and for pain, a higher score means a higher degree of pain; [a]: n = 235; [b]: n = 217, as twenty-one participants were not able to do the test; [c]: n = 237; [d]: n = 192; [e]: n = 178, as seventeen participants were not able to do the test; [f]: n = 194; [g]: n = 101; [h]: n = 96, as six participants were not able to do the test; [i]: n = 91; [j]: n = 82, as eleven participants were not able to do the test; [k]: n = 92; *: Independent samples t-test for continuous variables, Chi-squared test for dichotomous variables. A p-value < 0.05 is considered a statistically significant difference.

3.2 Association between factors and frequent participation

Fifty-two percent (n = 102/195) of the participants performed exercises of the home-based exercise program daily (n = 57) or a few days a week (n = 45), and so were classified as the frequent participation group. The infrequent or nonparticipation group consisted of participants performing exercises one day a week (n = 18), less than one day a week (n = 22), or not at all (n = 53). The most important reasons for not frequently participating, mentioned by the participants, were 'exercises are too easy' (29%), and 'poor health' (21%). At baseline, the demographic characteristics did not significantly differ between the frequent and infrequent or nonparticipation groups (Table 1). Health-related outcomes did differ significantly between the two groups, as the frequent participation group had a significantly higher quality of life, better self-management abilities, and better physical functioning (SF-20), than the infrequent or nonparticipation group. A significantly higher degree of pain (SF-20) was indicated by the frequent participation group, as well. In the univariate logistic regression analysis, a higher quality of life and better self-management abilities were significantly associated with frequent participation (Table 2). One factor that was not significantly associated in the univariate analysis, was significantly associated in multivariable models 1 and 2. Namely, a higher degree of pain (SF-20) was associated with frequent participation in multivariable model 1 (OR: 1.02, 95% CI: 1.01–1.04) and model 2 (OR: 1.02, 95% CI: 1.00–1.04).

Table 2. Factors associated with frequent participation in the home-based exercise program.

	Univariate		**Multivariable model 1†**		**Multivariable model 2‡**	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Female	1.33 (0.71–2.48)	0.38	1.40 (0.66–2.98)	0.38	1.12 (0.50–2.47)	0.79
Age	0.98 (0.94–1.03)	0.46	1.01 (0.96–1.06)	0.78	1.01 (0.95–1.06)	0.82
Living alone	1.11 (0.62–1.98)	0.73	0.88 (0.45–1.74)	0.72	0.82 (0.40–1.68)	0.59
Education						
low	0.68 (0.36–1.28)	0.23	1.14 (0.55–2.37)	0.72	1.51 (0.68–3.36)	0.32
middle	0.96 (0.55–1.69)	0.89	0.88 (0.42–1.82)	0.72	0.66 (0.30–1.48)	0.32
high	1.86 (0.86–4.00)	0.12	1.93 (0.83–4.46)	0.13	1.47 (0.60–3.62)	0.40
Quality of life (EQ-5D + cognition)	3.52 (1.16–10.71)	0.03	1.39 (0.21–9.31)	0.73	0.63 (0.07–6.12)	0.63
Elevated fall risk	0.72 (0.41–1.27)	0.25	1.00 (0.49–2.03)	1.00	0.96 (0.43–2.18)	0.93
Mobility (TUG) in seconds	0.99 (0.96–1.03)	0.72	1.02 (0.97–1.07)	0.47	1.01 (0.95–1.06)	0.84
Concern about falling (Short FES-I)	1.02 (0.96–1.09)	0.50	1.07 (0.98–1.17)	0.12	1.08 (0.98–1.18)	0.14
Self-management (SMAS-S)	1.03 (1.01–1.05)	0.00	1.02 (1.00–1.05)	0.09	1.01 (0.98–1.04)	0.64
General health (SF-20)						
physical functioning	1.01 (1.00–1.02)	0.07	1.00 (0.99–1.02)	0.67	1.00 (0.99–1.02)	0.69
role functioning	1.01 (1.00–1.01)	0.09	1.00 (0.99–1.01)	0.50	1.01 (0.99–1.02)	0.41
social functioning	1.01 (1.00–1.01)	0.27	1.00 (0.99–1.01)	0.89	1.00 (0.99–1.01)	0.91
mental health	1.00 (0.99–1.02)	0.70	0.99 (0.97–1.01)	0.20	0.98 (0.96–1.00)	0.98
current health perceptions	1.01 (1.00–1.02)	0.14	1.01 (0.99–1.03)	0.27	1.01 (0.99–1.04)	0.19
pain	1.01 (1.00–1.02)	0.10	1.02 (1.01–1.04)	0.00	1.02 (1.00–1.04)	0.02

†: Adjusted for baseline high education, and follow-up quality of life, self-management, physical functioning, role functioning, current health perceptions, and pain; ‡: Adjusted for baseline high education, quality of life, elevated fall risk, self-management, physical functioning, role functioning and pain, and follow-up quality of life, self-management, physical functioning, role functioning, current health perceptions, and pain; A p-value <0.05 is considered a statistically significant difference.

3.3 Effects of frequent participation on health-related outcomes

In multivariable model 1, the effect of frequent participation over time was a significant improvement in current health perceptions (SF-20) (B: 4.49, SE: 2.01) (Table 3). This effect was observed in multivariable model 2, as well (B: 4.46, SE: 1.99). The direction of this change can be derived from Supplementary Table S2, which shows the baseline and follow-up health-related outcomes of individuals frequently participating in the program.

Table 3. Effects of frequent participation in the home-based exercise program on health-related outcomes.

	Multivariable model 1†		**Multivariable model 2‡**	
Logistic Regression	OR (95% CI)	p-value	OR (95% CI)	p-value
Elevated fall risk	0.85 (0.43–1.71)	0.65	0.90 (0.42–1.94)	0.79
Linear regression	B (SE)	p-value	B (SE)	p-value
Quality of life (EQ-6D)	0.01 (0.03)	0.78	0.01 (0.03)	0.82
Mobility (TUG) in seconds	−0.10 (0.94)	0.92	−0.57 (0.91)	0.53
Concern about falling (Short FES-I)	0.30 (0.50)	0.55	0.56 (0.51)	0.27
Self-management (SMAS-S)	1.79 (1.55)	0.25	1.20 (1.58)	0.45
General health (SF-20)				
physical functioning	0.59 (3.49)	0.87	1.38 (3.53)	0.70
role functioning	2.91 (4.23)	0.49	2.43 (4.08)	0.55
social functioning	3.51 (4.32)	0.42	1.97 (4.37)	0.65
mental health	−0.29 (2.01)	0.89	−0.49 (2.06)	0.81
current health perceptions	4.49 (2.01)	0.03	4.46 (1.99)	0.03
pain	3.04 (3.59)	0.40	6.62 (3.60)	0.07

†: Adjusted for the baseline variable; ‡: Adjusted for the baseline variable, and baseline high education, quality of life, elevated fall risk, self-management, physical functioning, role functioning, and pain; A p-value < 0.05 is considered a statistically significant difference.

3.4 Multicollinearity

As shown in Table 2, the variable pain was not significantly associated in the univariate analyses, but was significantly associated in multivariable model 1 and 2. Therefore, multicollinearity could have influenced the results. The variable pain has a low correlation (0.30–0.50) with six independent variables. Furthermore, this variable does not have a VIF larger than three.

4. Discussion

The current study showed that 52% of the participants performed the exercises of the home-based exercise program frequently during the entire study period. At baseline, the frequent participation group had a significantly higher quality of life, better self-management abilities, better physical functioning, and a higher degree of pain than the infrequent or nonparticipation group. A higher degree of pain was associated with frequent participation. Also, our study observed that the effect of frequent participation over time was a significant improvement in current health perceptions. Several other studies have found that participation in an exercise program resulted in better health perceptions. Namely, three studies have shown that, among older adults, participation in a community exercise group, in a Pilates exercise group, or in Tai Chi has resulted in better health perceptions [24-26]. Frequent participation in the program was not associated with a lower fall risk or better mobility. An explanation could be that the study period was not long enough to detect clear associations or effects. For example, a meta-analysis of four Otago studies showed a reduction in falls and improvement in balance; however, fall events and balance were monitored for at least 44 weeks, whereas our study had only twelve weeks of follow-up [27]. A positive association between good self-rated health and participation has been observed in previous studies. Namely, among Mexican older adults, good self-rated health was associated with practicing regular physical activity [28]; among community-dwelling Japanese older adults, it was associated with high participation in sports groups [29]; and among community-dwelling white American older adults, it was associated with engaging in medium- or high-intensity activity [30]. In our study, we did not observe an association between good self-rated general health (SF-20) and frequent participation. An explanation for these differences in study results could be that 'exercise participation' was defined differently. Specifically, the cohort studies performed in Mexico, Japan, and in the United States classified participation as all physical activity that was performed in the past twelve months, whereas we classified participation as physical activity that was performed only in the exercise program. Furthermore, Hawley-Hague et al. (2016) published a review on studies reporting the level of participation of older adults in exercise programs [31]. They showed that there was hardly any consensus between studies on how to define the level of participation. Instead of an association between good self-rated health and participation, we observed that a higher degree of pain (SF-20) was associated with frequent participation. This could partly be explained by differences between participation groups at baseline. Specifically, at baseline, the frequent participation group had a higher degree of pain than the infrequent or nonparticipation group. However, the question remains why individuals with a higher degree of pain were more likely to participate frequently in the exercise program. A systematic review on older adults' perspectives reported that pain can be a barrier or facilitator for participation [32]. Even though exercise can be perceived as physically demanding, some older adults exercise in order to deal with or relieve pain. The percentage of individuals with frequent participation was relatively high in our study (52%), as a systematic review and meta-analysis showed that, on average, 21% of older adults are adherent in exercise interventions [10]. This can be explained by the fact that the program of the current study included balance and walking exercise, which have shown to increase participant adherence [10]. The participation level of the individuals who participated infrequently or not at all might have been higher if the exercises had been more challenging, as 29% of the participants mentioned that the exercises were too easy. A study by Elskamp et al. (2012) reported a similar result, as the older adults that refused to participate in their falls prevention interventions considered themselves to be too healthy [33]. Interestingly, a relatively old population (mean age 81.1 years) participated in the current study. The fact that the majority of participants were recruited through primary care health professionals, such as community nurses, could be an explanation. As in general, the oldest old receive homecare, this could have resulted in a relatively old population in the study. Another explanation could be that 'younger' older adults (i.e., those aged 64–75 years) prefer a group-based falls prevention program, whereas the oldest old prefer a home-based program [9]. As reported earlier in the results, the presence of multicollinearity could be an explanation for the variable pain to become statistically significant in the multivariable model 1 and 2. However, as the correlation with other independent variables is low, and it did not have a VIF larger than three, it is unlikely that multicollinearity has influenced the results. A strength of our study is that it resembles a real-life situation. Namely, in comparison to a program offered in a group on location, the participants of the current study could choose which home-based exercises they performed, and how often, without interference from the research team or a physiotherapist. Another strength of the study was that adherence was good, as 82% of the participants completed the program, with few avoidable dropouts. Furthermore, no statistically significant baseline differences between completers and dropouts were observed. A limitation of our study is that the level of participation was based on self-report and so is subject to social desirability bias. If participation had been monitored by the research team during the study period, participation levels might have been different. For example, if participation levels had been measured again after six weeks, the research team could have guided participants to exercise more often, which could have changed participation levels. However, this would have detracted from the real-life nature of this falls prevention program. In addition, the level of participation was administered with an ordinal scale. This has reduced the precision of the measurement. Another limitation was that no information was available on what type or duration of exercises of the instruction book were performed by the participants. Therefore, we were unable to determine what type or duration may have contributed to the changes in the outcomes. Furthermore, other physical activity, performed outside of the study, was not assessed and thus could not be adjusted for in the analyses. The studied population might not be representative of general community-dwelling older adults. Specifically, as the majority of older adults were recruited through primary care health professionals, the participants of the current study might have been older and more frail than the general older adult population. Therefore, selection bias might have been present.

5. Conclusion

This study shows that the participant characteristic pain was associated with frequent participation in a home-based exercise program. Furthermore, the effect of frequent participation over time was a significant improvement in current health perceptions (SF-20). These characteristics should be taken into account in the planning of future falls prevention interventions. By monitoring these characteristics during an intervention, it is possible to guide and motivate specific participants, so that frequent participation rates will increase.

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7. Supplementary material

Supplementary Table S1. Baseline characteristics of completers and drop-outs of the home-based exercise program, and differences between both groups.

	Completers (n=195)	**Drop-outs (n=43)**	**Difference between completers and drop-outs***
Demographic characteristics	n (%)	n (%)	p-value
Female	140 (72)	29 (67)	0.57
Age - mean ± SD	80.9 ± 6.6	82.2 ± 6.9	0.24
Living alone	124 (64)	27 (63)	0.92
Education			
low	53 (27)	17 (40)	0.11
middle	108 (55)	22 (51)	0.62
high	34 (17)	4 (9)	0.19
Health-related outcomes	mean ± SD	mean ± SD	p-value
Quality of life (EQ-5D + cognition)1	0.65 ± 0.24	0.61 ± 0.23	0.35
Elevated fall risk - n (%)	133 (69)[a]	28 (65)	0.60
Mobility (TUG) in seconds	16.9 ± 8.9[b]	17.8 ± 9.8[d]	0.58
Concern about falling (Short FES-I)	9.8 ± 3.9	9.7 ± 4.7	0.84
Self-management (SMAS-S)2	60.1 ± 16.0[c]	55.4 ± 16.5	0.08
General health (SF-20)3			
physical functioning	45.1 ± 31.6[c]	45.0 ± 32.4	0.98
role functioning	29.2 ± 41.1	26.7 ± 42.7	0.72
social functioning	74.5 ± 32.7	63.7 ± 38.6	0.10
mental health	73.2 ± 20.8[c]	72.3 ± 20.5	0.79
current health perceptions	46.9 ± 21.1[c]	44.1 ± 21.4	0.43
pain	31.9 ± 27.8	37.8 ± 26.9	0.21

SD: Standard deviation; 1: Mean scores range from 0 (death) to 1 (full health); 2: Scores range from 0-100, a higher score means better self-management abilities; 3: Scores range from 0-100, a higher score means better functioning, and for pain, a higher score means a higher degree of pain; [a]: n=192; [b]: n=178, as seventeen participants were not able to do the test; [c]: n=194; [d]: n=39, as four participants were not able to do the test; *: Independent samples t-test for continuous variables, Chi-squared test for dichotomous variables. A p-value <0.05 is considered a statistically significant difference.

Supplementary Table S2. Baseline and follow-up health-related outcomes of individuals frequently participating in the home-based exercise program.

	Baseline frequent participation (n=102)	**Follow-up frequent participation (n=102)**
Health-related outcomes	mean ± SD	mean ± SD
Quality of life (EQ-5D + cognition)1	0.70 ± 0.23	0.70 ± 0.26[c]
Elevated fall risk - n (%)	65 (64)[a]	
Mobility (TUG) in seconds	16.2 ± 7.9[b]	16.9 ± 9.1[d]
Concern about falling (Short FES-I)	9.9 ± 3.6	9.9 ± 4.3c
Self-management (SMAS-S)2	63.8 ± 14.9	61.6 ± 14.5
General health (SF-20)3		
physical functioning	50.2 ± 32.0	51.7 ± 31.1[e]
role functioning	34.3 ± 43.9	36.3 ± 42.3
social functioning	76.3 ± 32.5	73.9 ± 33.4
mental health	74.1 ± 20.8[a]	75.1 ± 20.8
current health perceptions	47.1 ± 20.5	49.0 ± 19.4[c]
pain	35.8 ± 27.1	36.0 ± 26.7

SD: Standard deviation; 1: Mean scores range from 0 (death) to 1 (full health); 2: Scores range from 0-100, a higher score means better self-management abilities; 3: Scores range from 0-100, a higher score means better functioning, and for pain, a higher score means a higher degree of pain; [a]: n=101; [b]: n=96, as six participants were not able to do the test; [c]: n=101; [d]: n=82, as twenty participants were not able to do the test; [e]: n=100.

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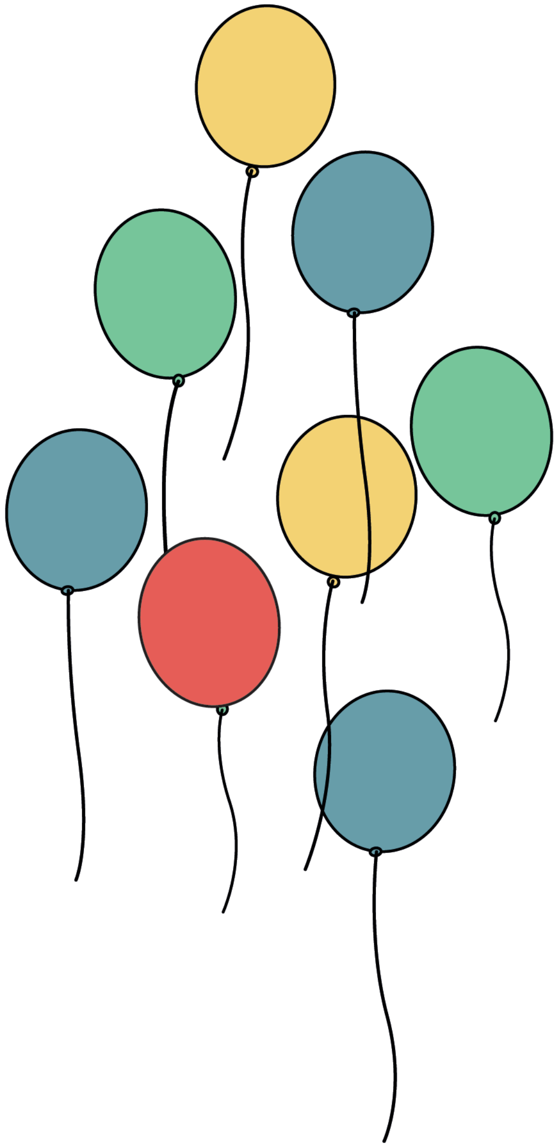

CHAPTER 8

Personal preferences of participation in falls prevention programs

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Submitted

Abstract

Participation in falls prevention programs is limited and might increase with a preference based approach. In this study we assessed the personal preferences of older adults and the association between these preferences, chosen falls prevention program and participation. Community-dwelling older adults, aged ≥65, were offered nine different falls prevention programs, with a suggestion based on individual preferences (e.g. alone or in a group, at home or at external location) participants had. Twelve weeks after the start of the program, participation was assessed by questionnaire. Among the participants, 49% preferred to exercise at home versus 44% elsewhere, 46% preferred to exercise alone versus 45% in a group and 42% only wanted to participate free of charge while 52% was willing to pay. The combination, at an external location, in a group and for a fee was preferred by 26% of the participants, whereas another 25% a program at home, alone and for free. The extent to which the chosen program matched personal preferences did not seem to affect participation level. Despite the fact that preferences vary greatly between older adults, some subgroups can be distinguished. However, the presence of preferences did not influence participation level.

1. Introduction

More than one-third of community-dwelling older adults, aged ≥65 years fall each year [1]. Because of the aging population, the number of falls in older adults is expected to rise [2]. Among the older adults who fall, 66% gets injured, of which 20% visits the hospital, and 11% require a hospital admission [3]. Fall-related injuries have a substantial impact on the quality of life of individuals and on health care costs, making them a major public health problem [4, 5]. Research has shown that exercise interventions can reduce falls and fall-related-injuries [6-10]. However, participation rates in falls prevention interventions are low [11]. Often, older adults are not reached [12], they are not aware of their risk [13], or they are not willing to participate [14]. When reached, personal factors, not seeing the personal relevance of falls prevention programs, and transportation problems are among the reasons to reject such interventions [15-17]. Individually tailored falls prevention programs might increase the chance that older adults will like and enjoy the program, which has a positive influence on participation rates and active participation [17-20]. In our study, we offered a wide variance of preference-based falls prevention programs in order to investigate if such an approach can stimulate participation. Therefore, the aims of this study are to determine; a) what the personal preferences of older adults are in participating in a falls prevention program, and b) what the influence of personal preferences is on participation level.

2. Materials and methods

Within this observational study, older adults received an overview of available falls prevention programs in their neighbourhood, and a suggestion of a twelve-week exercise program, based on their own preferences. Older adults were free to choose the program they preferred. A questionnaire was administered at baseline and twelve weeks after commencement of the chosen program. This study was conducted from June 2017 until December 2018 among community-dwelling adults aged ≥65 years, living in the city of Breda, in the Netherlands. Not understanding the Dutch language, dementia and living in a residential care facility were exclusion criteria. All participants provided informed consent. The medical ethics committee of Erasmus MC, University Medical Center Rotterdam reviewed the study and waived ethical approval (number 2017-139).

2.1 Falls prevention programs

Falls prevention programs were offered with an integrated neighbourhood approach to achieve a better balance between community-dwelling older adults in need for care and local healthcare givers [21, 22]. To achieve this balance for every neighbourhood, profiles of the neighbourhood were developed, relevant stakeholders were approached and different meetings were organized with these stakeholders to discuss the implementation of the programs. Among the stakeholders were local healthcare providers, older adult organizations, volunteers, and local initiatives for older adults [23]. They partly facilitated the recruitment, in addition to the recruitment of the research team, and offered the falls prevention programs. With this collaboration, older adults could participate in a program of their own choice, within their own neighbourhood, stimulated and provided by a local healthcare provider. A total of nine exercise-based falls prevention programs were offered in the city of Breda. The number of available programs within each neighbourhood differed, but there was a minimum of four programs per neighbourhood. The programs, described in more detail below, are 'In balans', 'Vallen verleden tijd', 'Otago', 'Zicht op evenwicht', 'Samen door', 'Senior Stap', 'Valanalyse', senior fitness, and individual physiotherapy. The effect of the programs on falls or fall risk were not the focus of this study since most programs were evidence based interventions.

(1) 'In balans' (in balance) is an evidence based intensive group program that is led by a physiotherapist, consisting of information sessions and an exercise program, which aims to increase risk awareness, and improve balance, mobility, physical fitness, and self-confidence [10].
(2) 'Vallen verleden tijd' (falls in the past) is an evidence based intensive group program that is led by a physiotherapist, consisting of an obstacle course, sports and games, and fall techniques, which aims to improve mobility and reduce the fear of falling [9].
(3) 'Otago' is an evidence based program tailored to the individual that is led by a physiotherapist and is offered at home, it consists of leg and balance exercises, and a walking program, which aims to improve muscle strength and balance [7].
(4) 'Zicht op evenwicht' (a matter of balance) is an evidence based program that is led by a physiotherapist at home or at location, which aims to reduce the fear of falling and increase the perceived social support [24].
(5) 'Senior Step' is a home-based program that is performed individually, consisting of an instruction book with exercises that can be performed at home, in order to improve balance, mobility, and strength [6].
(6) 'Samen door' (go together) is an individual, home-based program in which a physiotherapist discusses with the participant what help is needed. Then, a volunteer is linked to the participant to help out [25].
(7) 'Valanalyse' (fall analysis) is an individual, home-based program that is led by an occupational therapist, which consists of a risk assessment and a tailored advice in order to reduce the risk of a fall. Besides options of exercise training, other risk factors like medication and vision are also taken into account [26].
(8) Senior fitness is a group program that is led by a physiotherapist in practice, which aims to improve balance and mobility.
(9) Individual physiotherapy is a treatment that is given at home or at location in which extra attention is being paid to balance and mobility.

2.2 Preferences and baseline characteristics

The recruitment of participants is described in earlier publications of the study [23, 27]. Once participants applied for the study, an informed consent was sent by mail, accompanied by questions to assess fall risk. After written informed consent was provided, the individual was called by a member of the research team to assess personal preferences and an appointment was scheduled to administer a baseline questionnaire. It was intended to administer this questionnaire during a home visit. However, due to the time investment of visiting participants at home, we could not offer all participants this home visit. When time was insufficient, the questionnaire was administered by telephone.

2.2.1. Fall risk

Fall risk was assessed by three questions; 1) did you fall in the past twelve months?; 2) do you experience problems with movement and balance?; and 3) are you afraid of falling? Older adults that answered yes on question 1, or on two out of the three questions, were considered as having a high fall risk [26].

2.2.2. Preferences

Preferences of participating in a falls prevention program were collected over phone. This consisted of seven questions with two answer options. The questions posed were drafted together with a panel of older adults, in a participatory design approach. These older adults were part of a forum, which aims to improve the quality of life and care of older adults [28]. This resulted in the following questions: Do you prefer a program; 1) at home or at an external location? 2) individually or in a group? 3) requiring payment or do you only want to participate if it is for free? 4) on fixed times or whenever it is convenient for you? 5) at a high or low intensity? 6) in which sportive factors or social factors are more important? 7) with men or women separately, or together?

2.2.3 Baseline characteristics

A baseline questionnaire was assessed by a member of the research team during a home visit or telephonically. This questionnaire included items on sociodemographic characteristics, such as age, sex, living situation, marital status, country of birth and education level. Education was arranged in low (less than primary school, primary school, and little more than primary school), middle (i.e. technical school, vocational education, general secondary/pre-university education), and high (i.e. college/university). Furthermore, it took into account health-related quality of life by the three level EuroQol instrument (EQ-5D + cognition), in which the domains mobility, self-care, usual activities, pain and discomfort, anxiety and depression, and cognition were taken into account [29]. A summary score ranged from 0 (death) until 1 (full health).

2.3 Referral

During the home visit or telephone call, the participant was provided with flyers of all falls prevention programs that were available in his or her neighbourhood, while one or more programs, best matching the preferences of the participant, were suggested by a member of the research team. A member of the research team telephoned the participant two weeks later to enquire whether a program was chosen. Once a participant chose a program, a member of the research team initiated the first contact with the local healthcare provider that offered the program. The healthcare provider contacted the participant and made an appointment to start the falls prevention program. In some cases participants could start straight away (e.g. individual programs); in other cases participants received a date when their chosen program would start in the future (e.g. for groups programs).

2.4 Follow-up characteristics

Twelve weeks after the start of the program, a member of the research team called the participant again and a follow-up questionnaire about participation was administered. Frequent participation was classified as performing exercises of the falls prevention program daily or a few days a week during the twelve week study period. Infrequent or nonparticipation was classified as performing exercises one day a week, less than one day a week, or not at all. These classifications are described in an earlier publication of the study [27]. Furthermore participants experiences with and perceptions of the program were assessed, see Supplementary Table S1.

2.5 Statistical analyses

For baseline and follow-up characteristics, continuous variables are expressed as mean and range, dichotomous variables and preferences are expressed as number and percentage. Differences at baseline between participants with a low and high fall risk were compared using an independent t-test for continuous variables and a chi-squared test for dichotomous variables. In order to determine the correlation between participants in terms of their personal preferences, a two-tailed Pearson correlation was used. To investigate whether there was an association between baseline personal preferences and the presence of the preferences in the program individuals participated in, Cramer's V correlations were performed. For the influences of particular preferences on chosen falls prevention programs, logistic regressions were used in where the presence of the preferences were used as independent variables and the frequent participation as dependent variable. In order to plot the number of preferences that were eventually present in the falls prevention program against the follow-up characteristics, an ANOVA test was performed. A distinction was made between participants for which five out of seven or less preferences were eventually present, six out of seven preferences were present, or all seven preferences were present in the program. In all analyses a p-value of $<.05$ was considered statistically significant. Analyses were performed using SPSS Statistical Data software (IBM), version 24.

3. Results

Of all older adults reached during recruitment, 222 older adults were interested in following a falls prevention program. Due to a dropout of 92 older adults, eventually 130 older adults indicated that they wanted to start with a particular program, in which we saw no difference between high and low risk older adults. In the end 112 older adults started with a program of which 94 finished it (Figure 1). From the start onwards, a total loss of 128 participants was seen. Of them, 32 were loss due to follow up. Of the remaining 96, reasons for dropout during the process were: older adults experienced health problems which made participation impossible for them, older adults thought they did not need a falls prevention program (any more) or the programs available during that time did not met their preferences.

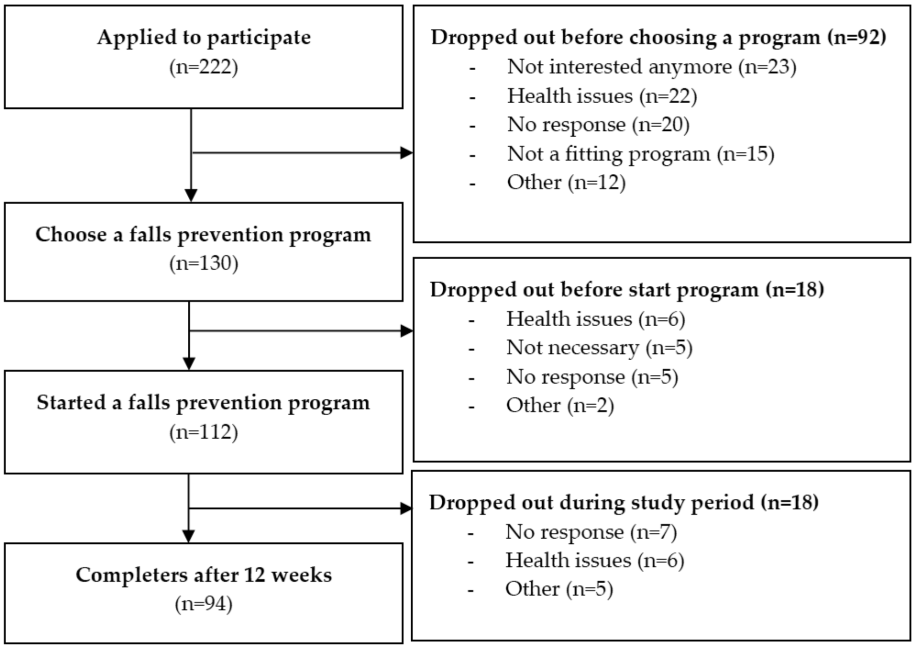

Figure 1. Flowchart of participants in the falls prevention programs.

3.1 Basic characteristics

Baseline characteristics were administered from 138 participants (Table 1). Mean age of participants was 80.8 years, most were women, Dutch, lived independently and were widow/widower. Most participants indicated to have problems with mobility (72%) and usual activities (64%). Furthermore, 70% of the participants indicated experiencing pain and discomfort. In 64% of the participants a high fall risk was detected. Several differences between participants with a high and low fall risk were observed. Namely, participants with a high fall risk had a lower EQ-5D utility score than those with a low fall risk (0.55 vs 0.71, p-value: <.001). Also participants with a high fall risk had more problems with mobility (85% vs 52%, p-value: <.001), self-care (52% vs 22%, p-value: .001), and daily activities (78% vs 40%, p-value: <.001) than participants with a low fall risk.

Table 1. Baseline characteristics of all participants (n=138) and differences between participants with a high and a low fall risk.

Characteristics	Total (n = 138)	High risk (64%) (n = 87)	No/low risk (36%) (n = 50)	p-value T-test or chi-square*
Age (mean, range)	80.8 (65-99)	81.0 (65-99)	80.7 (65-95)	.793
Gender (n, %)				.867
Men	34 (24.6%)	22 (25.3%)	12 (24%)	
Women	104 (75.4%)	65 (74.7%)	38 (76%)	
Country of birth (n, %)				.019
Netherlands	128 (92.8%)	78 (89.7%)	50 (100%)	
Other	10 (7.2%)	9 (10.3%)	0 (0%)	
Education (n, %)				
Low	47 (34.1%)	34 (39.1%)	13 (26%)	.121
Middle	68 (49.3%)	36 (41.4%)	31 (62%)	.020
High	23 (16.7%)	17 (19.5%)	6 (12%)	.256
Living situation (n, %)				.808
Independent	104 (75.4%)	66 (75.9%)	37 (74%)	
Independent with others	34 (24.6%)	21 (24.1%)	13 (26%)	
Marital status (n, %)				
Married	34 (24.6%)	21 (24.1%)	13 (26%)	.808
Divorced	10 (7.2%)	8 (9.2%)	1 (2.0%)	.102
Widow/widower	81 (58.7%)	52 (59.8%)	29 (58%)	.839
Unmarried	11 (8.0%)	5 (5.7%)	6 (12%)	.195
Sustainably living together	2 (1.4%)	1 (1.1%)	1 (2%)	.689
EQ 5D weight score (mean, range)	0.61 (0.13-1)	0.55 (0.13-1)	0.71 (0.18-1)	< .001
Problems with (n, %)				
Mobility	100 (72.5%)	74 (85.1%)	26 (52%)	<.001
Selfcare	56 (40.6%)	45 (51.7%)	11 (22%)	.001
Daily activities	89 (64.5%)	68 (78.2%)	20 (40%)	<.001
Pain/discomfort	97 (70.3%)	62 (71.3%)	35 (70%)	.875
Mood	46 (33.3%)	32 (36.8%)	14 (28%)	.295
Cognition	45 (32.8%)	32 (36.8%)	13 (26%)	.196

*An independent t-test was used for continuous variables and an chi-squared for dichotomous variables. A p-value of <.05 is considered statistically significant.

3.2 Preferences

Of all participants, 49% specified they preferred a falls prevention program at home versus 44% that preferred a program at a location outside their home. An individual falls prevention program was preferred by 46% versus 45% that preferred the option in a group. Most of the participants were willing to pay (52%) for a falls prevention program, although 42% of the participants indicated that they only wanted to participate in a falls prevention program free of charge. Some participants did not have a clear preference for one of the two options. An overview of other preferences can be found in Figure 2. There was a positive correlation between participants that preferred to exercise at home and individually (R .772, p-value <.001). Furthermore, there was a positive correlation between participants that preferred to exercise at an external location and in a group (R .767, p-value <.001). When looking at combinations of the preferences at home or at an external location, alone or in a group and only for free or willing to pay, two subgroups can be distinguished. Specifically, 26% of participants prefers a program at an external location, in a group, and for a fee whereas another 25% of participants prefers a program at home, alone, and only for free. When comparing participants with a high and a low fall risk, a larger percentage of those with a high fall risk prefers to exercise at home (59% vs 34%, p-value: .006) and alone (57% vs 30%, p-value: <.001) than those with a low fall risk.

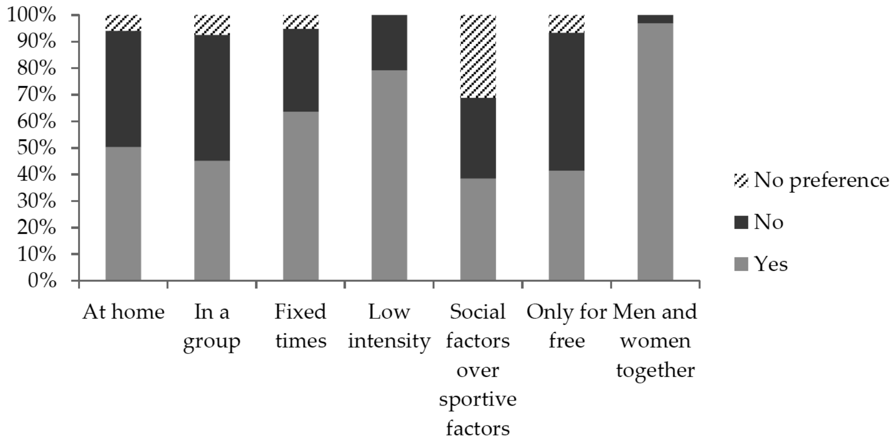

Figure 2. Exercise preferences of participants regarding falls prevention (n=135).

3.3 Falls prevention programs

For 31 participants (32%), six out of seven preferences were present, and for 38 participants (39%), all preferences were present in the falls prevention program they started. If five or less preferences were met, still for 19 participants (20%) four or five preferences were met and only for nine participants (9%) three or less preferences were met. Eventually the majority of participants started with an individual-based falls prevention program (62%), free of charge (63%). When comparing participants with a high and low fall risk, a larger percentage of those with a high fall risk started with an individual-based program (71% vs 49%, p-value: .014) and free of charge (71% vs 51%, p-value: .025) than those with a low fall risk. An overview of falls prevention programs chosen by participants can be found in Table 2.

Table 2. Chosen falls prevention programs (n=130) and differences in programs between participants with a high and a low fall risk.

Program	**Total (n=130)**	**High risk (63%) (n=82)**	**No/low risk (37%) (n=47)**	**Chi-square***
	n (%)	n (%)	n (%)	p-value
In Balance	17 (13.1%)	10 (12.2%)	7 (14.9%)	0.663
Falls in the past	16 (12.3%)	7 (8.5%)	9 (19.1%)	0.078
Otago / A matter of balance	13 (10%)	9 (11%)	4 (8.5%)	0.654
Senior Step	21 (16.2%)	13 (15.9%)	8 (17%)	0.863
Fall analysis	18 (13.8%)	12 (14.6%)	6 (12.8%)	0.768
Individual physiotherapy	20 (15.4%)	17 (20.7%)	3 (6.4%)	0.030
Senior fitness	16 (11.4%)	7 (8.5%)	8 (17%)	0.148
Go together	9 (6.9%)	7 (8.5%)	2 (4.3%)	0.358

*A p-value of <.05 is considered statistically significant.

When comparing the association of personal preference and characteristic of chosen programs, some preferences have a moderate to strong association, such as the preferences “on location” (V .616, p-value: <.001), “at home” (V .583, p-value: <.001) and “in a group” (V .560, p-value <.001). For the preferences high or low intensity, social or sportive factors and genders mixed or genders separated, no association was found. More associations can be found in Table 3.

Table 3. Overview of the correlations between the baseline personal preferences and the presence of these preferences in the falls prevention program individuals participated in.

Preference	**Cramer’s V correlation at preferred option**	
	Value	**Significance**
At home	.583	<.001
External location	.616	<.001
Individually	.486	<.001
Group	.560	<.001
Own time	.336	<.001
Fixed time	.289	.001
Low intensity	.024	.782
High intensity	.055	.532
Social factors	.135	.125
Sportive factors	.046	.599
For free	.376	<.001
Willing to pay	.302	.001
Gender separate	.043	.625
Gender mixed	.030	.731

3.4. Follow-up characteristics

Frequent participation during the study period was indicated by 34 (38%) participants. A total of 64 (74%) participants said that their program was useful, 46 (52%) said that they liked the program, 48 (55%) noticed a change in the awareness of their fall risk, 32 (38%) noticed an increased confidence in their balance, and 29 (35%) participants noticed a change in their level of physical activity. In Figure 3, the number of preferences that were present in the falls prevention program is plotted against the follow-up characteristics. A distinction was made between participants that followed a program in which five or fewer preferences were present, six preferences were present, or all preferences were present in the program. Participants that participated in a program in which six of their preferences were present, were more likely to be aware of their fall risk than participants at which less than six or all preferences were present in the program ($F(2, 58)$: 6.452, p-value: .003). No statistically significant association was observed between the presence of personal preferences in the program, and the level of participation in the program. In addition, no association was found between the presence of particular preferences and participation level.

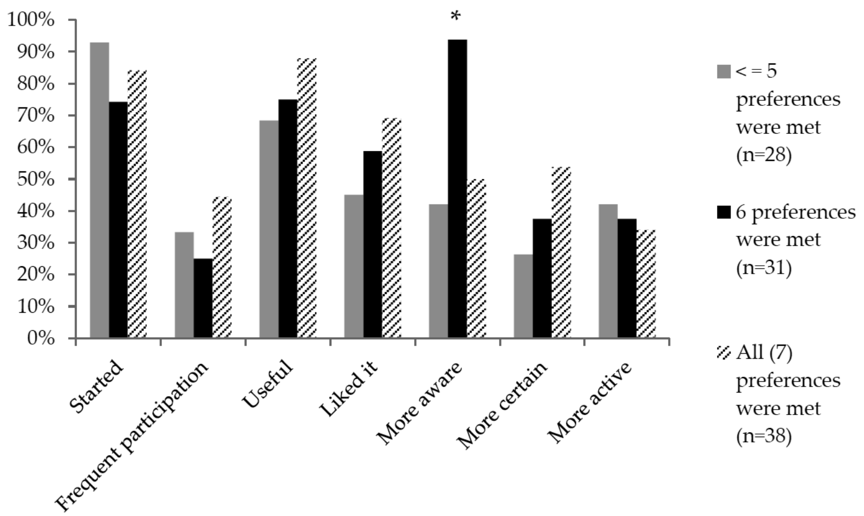

Figure 3. The amount of preferences that were present in the falls prevention program, plotted against the follow-up characteristics. *Significant (p = <.05) difference between the groups.

4. Discussion

We found that 49% of participants preferred to exercise at home versus 44% elsewhere, 46% preferred to exercise individually versus 45% in a group, and 42% only wanted to participate in a program free of charge versus 52% that is willing to pay. Two subgroups could be distinguished with these preferences, namely a subgroup that prefers a program outside their own home, in a group and are willing to pay (26%) and a group that prefers a program at home, alone and are not willing to pay (25%). For 38 (39%) participants, all personal preferences were present in the program they started. However, the number of personal preferences or a particular preference in the program did not result in a change in the level of participation. The personal preferences of participants in our study varied much between individuals. This preference variation between older adults has also been confirmed by a previous study [20]. However, in our study, the majority of participants chose three clear preferences; mixed gender, low intensity, and fixed times. Even though, in general, the majority of exercise programs are offered at an external location, older adults appear to prefer a home-based program [30-32]. In our study we found that this 'at home' option was more often preferred and chosen among high risk older adults. This difference between older adults at a low and high risk is supported by a study of Dorresteijn et al. in which older adults with a history of multiple falls are more likely to prefer a homed-based program [30]. In our study, 64% of the participants had a high fall risk, which is linked to a history of falls. Furthermore, we found that more than half of the older adults is willing to pay for an intervention, which is supported by Child et al. who found that older adults are willing to pay as long as it is reasonable [18]. However, still 42% indicates that they do not want or cannot pay for a falls prevention program. It is important to consider this population, since costs can be a barrier for participation in falls prevention [31]. In addition to these mentioned preferences, we could distinguish two subgroups when it comes to preferences. These groups accounted for half of the total cohort which makes it important to create an appropriate offer for these groups. Based on these preferences, there should be a falls prevention program which can be used at home, alone and for free and a program outside participants home, in a group and with a possibility for a fee. In the Netherlands, these options are available for both groups but they are not widely offered. This causes poor accessibility of the programs and especially for programs at an external location. The availability of programs within the own neighbourhood of older adults is important, since transportation problems are an important reason for older adults to reject interventions [15, 18]. The fact that no association was found between the presence of personal preferences in the program and the level of participation could suggest that other factors might be more important. Factors such as the social component of a group, a good relationship with the provider or current health status might be more important [33-35]. Also, intrinsic motivation could play a more important role in the uptake of falls prevention. This reasoning can be supported by the reasons why older adults participate in the first place, namely staying in good health the fear of vulnerability [17, 20]. Furthermore, this intrinsic motivation could also arise from a recent fall or a great amount of falls in the past, which is associated with a higher uptake of falls prevention programs [32]. Despite the fact that we found some factors that were associated with the characteristics of chosen programs, we cannot conclude that these are the most important factors for older adults to participate. In the current study, this association is strongly associated with the available offer of falls prevention programs during the study period. To find out precisely which factors are most important for older adults, more research is needed, for example through a discrete choice experiment (DCE). This study shows a clear overview of preferences community-dwelling older adults have when it comes to participating in falls prevention programs. In the current study more than six out of seven preferences were eventually present in the falls prevention program of 71% of the participants. This was made possible as we managed to offer a total of nine different programs to the participants, which increased the chances of a possible 'match'. In addition, these falls prevention programs were all already on offer locally (offered by local health care providers) and not explicitly during the study period. However, some participants did not start a program as there was no program matching their preferences available during the study period. So, despite the broad offer of falls prevention programs, there is still a gap between older adults preferences and the available falls prevention programs. This gap caused some dropout, which is a limitation of the current study. Dropout was a concern in this study. From the 222 older adults applied to participate, 112 individuals participated in the study. A reason that was often mentioned was 'poor health', which has been observed in other studies, as well [17, 20]. Another reason for dropout could have been the delay between the decision for a program and the moment the program started. This sometimes took more than a month. In this period poor health, or a drop in motivation could have taken place among participants. This high dropout could have influenced the results. Older adults that had reasons to dropout in earlier stages might be less intrinsic motivated and maybe for that reason more influenced by preferences returning in the programs. Lastly, we are only able to make conclusions about this cohort, given that this is a rather old, Caucasian and vulnerable population with a high amount of women, which raises the question if this population is generalizable. However, this is a reflection of the older Caucasian race, especially for an older community dwelling population. When implementing falls prevention programs locally, it should be taken into account that preferences can vary greatly between older adults. Local policy makers together with health care providers should arrange applicable programs for the two largest subgroups, 1) at home, individually and free of charge and 2) a group outside their own home, in a group with the possibility of a fee. Another aspect that should be taken into account is the preference for a program free of costs. Despite the fact that most older adults were willing to pay (52%) for a falls prevention program, this still left 42% of the older adults not willing or not able to pay. Falls prevention programs free of charge or completely covered by health insurance are limited, while investing in exercise based falls prevention programs is cost-effective [36]. To prevent falls among this population it is important to offer a program free of charge or covered by health insurances. Finally, when targeting on adults with a high fall risk, the offer of programs should mainly focus on individual programs at home, since this is mostly preferred by this high risk population. Nevertheless, health care providers and local policy makers have to be careful in adopting to personal preferences of older adults because, it is unknown if programs remain effective by adopting to these preferences. A review of Sherrington et al. showed that exercise interventions have to consist of specific exercises and a certain intensity-level to be effective [37]. Adopting to personal preferences could be at the expense of these exercises or intensity and thus reduce the effectiveness.

5. Conclusion

There is a wide range of preferences when it comes to participating in a falls prevention program. However, there is a large group that prefers a falls prevention program at home, alone and for free and a large group that prefers a program outside their own home, in a group and is willing to pay for it. Besides, adults already at high risk for falls more often prefer an individual program at home. Especially, the preferences location (at home or an external location) and in a group are often found in the programs participants started. However, once older adults start with falls prevention, these preferences seem less important. There is no difference between participants following a program that matches their preference very well, to those that chose a less matching program.

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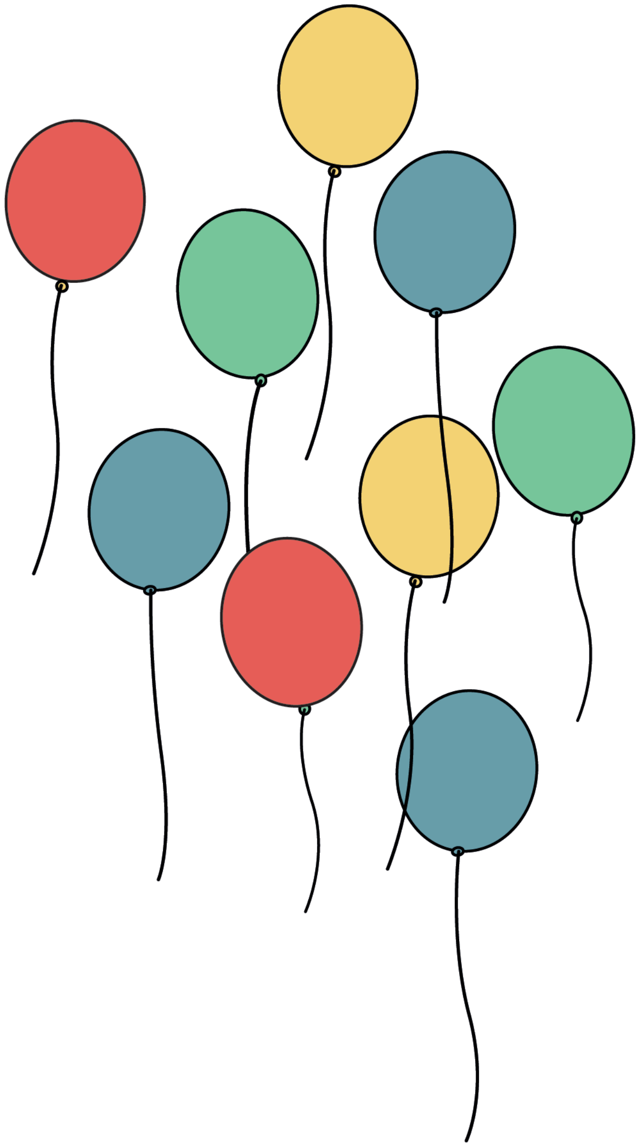
7. Supplementary material

Supplementary Table S1. Classification of follow-up characteristics.

Questions	Answers	Classification
Did you get started with the falls prevention program?	1. Yes 2. No	
How often did you perform actions of the falls prevention program?	1. Daily 2. Multiple times a week 3. Once a week 4. Less than once a week	Daily or multiple times a week is classified as "Frequent participation". Once a week or less than once a week is classified as "Non-frequent participation".
How much did you like the program?	1. Not nice at all 2. A little nice 3. Pretty nice 4. Very nice	Not nice at all and a little nice is classified as "Did not like it" Pretty nice and very nice is classified as "Liked it".
How useful did you find the program?	1. Not useful at all 2. A little useful 3. Pretty useful 4. Very useful	Not useful at all and a little useful is classified as "Not useful". Pretty useful and very useful is classified as "Useful".
Since I have participated in the falls prevention program, I am more aware of my fall risk.	1. Strongly disagree 2. Disagree 3. Neither agree or disagree 4. Agree 5. Strongly agree	Strongly disagree, disagree and neither agree or disagree is classified as "Disagree". Agree and strongly agree is classified as "Agree".
Since I have participated in the falls prevention program, I feel more secure while standing and walking.	1. Strongly disagree 2. Disagree 3. Neither agree or disagree 4. Agree 5. Strongly agree	Strongly disagree, disagree and neither agree or disagree is classified as "Disagree". Agree and strongly agree is classified as "Agree".
Since I have participated in the falls prevention program, I exercise more often.	1. Strongly disagree 2. Disagree 3. Neither agree or disagree 4. Agree 5. Strongly agree	Strongly disagree, disagree and neither agree or disagree is classified as "Disagree". Agree and strongly agree is classified as "Agree".



CHAPTER 9

General discussion

The ultimate aim of this thesis was to explore the impact and prevention of fall-related injuries among older adults. Chapter 9 describes and interprets the main findings of Chapter 2 through 8. Furthermore, methodological considerations, and recommendations and implications for research, policy, and practice are described.

Main findings

This thesis consists of three parts with corresponding aims.

Part I: The burden of fall-related injury and mortality

1. To describe the burden over time of fall-related injury and mortality among older adults.

The burden of fall-related injury and mortality among European older adults is large. One in eight older adults sought medical treatment following fall-related injury in 2016. Furthermore, in the Netherlands, the absolute number of fall-related Emergency Department (ED) visits increased by 48%, hospital admissions increased by 59%, and mortality showed an almost threefold increase, in the past two decades.

Chapter 2 described a study that used Global Burden of Disease (GBD) data of 22 European countries. There was considerable variation between countries in the fall-related incidence, burden of disease, and mortality. If the rates of falls among older adults could be lowered to those countries with the lowest levels, 821 disability-adjusted life years (DALYs) per 100,000 individuals could be averted.

The study described in Chapter 3 combined data on fall-related ED visits, hospital admissions, and mortality among Dutch older adults, between 1997 and 2016. Even though the absolute number of fall-related ED visits increased, standardized incidence rates of ED visits decreased over time. The absolute number of hospital admission days almost halved in the past two decades, due to a reduced average length of hospital stay from 18.5 days to 6.1 days.

Part II: Cost-effectiveness of falls prevention

2. To systematically evaluate the cost-effectiveness of falls prevention programs.

The majority of falls prevention programs were considered cost-effective. Specifically, about two-thirds of all studies reported an incremental cost-effectiveness ratio (ICER) – with quality-adjusted life-years (QALY) as utility measure – below a willingness-to-pay threshold of $50,000 per QALY.

A systematic review, with an overview of all published economic evaluation studies on falls prevention was presented in Chapter 4. In this review, a total of 31 studies on the cost-effectiveness of falls prevention programs among older adults were included. A home assessment program was the most cost-effective program for community-dwelling older adults (ICER < $40,000/QALY), and a medication adjustment program was the most cost-effective program for older adults living in a residential care facility (ICER < $13,000/QALY). Even though there was variation in the methodological quality between studies, the average quality score was good (84%).

Part III: Falls prevention in a community setting

3. To determine the conditions for successful implementation of falls prevention in a community setting.

In order to successfully implement falls prevention in a community setting, it is important to particularly involve the general practitioner, physiotherapist, community nurse, and informal caregiver.

These individuals are key in recruiting participants, stimulating participation, and offering proven-effective programs in a community setting.
The study of Chapter 5 consisted of a two-round online Delphi study on the current falls prevention activities of Dutch healthcare professionals. According to the panel, regular detection programs targeting older adults with a fall risk are rare, referral to falls prevention programs is lacking, and structural follow-up is hardly ever offered. In addition, older adults are reluctant to participate in an annual assessment of fall risk. Participation could be stimulated by a combination of national health education, healthcare counselling, and removal of financial barriers. Chapter 6, 7, and 8 reported on the *Houd ouderen op de been* study. In this study, falls prevention interventions were implemented in a community setting among older adults, in the city of Breda, in the Netherlands. Chapter 6 described a study in which the implementation of a twelve-week home-based exercise program was evaluated, using the framework model RE-AIM. A total of 238 older adults participated in the twelve-week program, of which the majority were recruited by a community nurse. A good collaboration between the research team and the local primary healthcare providers was accomplished, which was important in the recruitment of participants. The study of Chapter 7 investigated which factors were associated with frequent participation in the home-based exercise program. The effect of frequent participation on health-related outcomes over time was investigated, as well. Fifty-two percent of the participants indicated that they frequently participated, which means that exercises of the program were performed daily or a few days per week during the study period. Analyses indicated that a higher degree of pain was associated with frequent participation, and the effect of frequent participation over time was a significant improvement in current health perceptions. Chapter 8 described a study in which nine different exercise-based falls prevention interventions were offered to older adults (n=138), for twelve weeks. The study investigated the association between personal preferences, chosen falls prevention intervention, and participation rates. The preferences varied greatly between participants, as one group (26%) preferred a program at an external location, in a group, and for a fee, whereas another group (25%) preferred a program at home, alone, and for free. When the personal preferences of a participant were met, the participant was not more likely to frequently participate in the intervention.

Methodological considerations

Data sources on falls

Several European countries have population-based data available on fall-related morbidity and mortality. With this data, it is possible to describe and quantify trends over time, which may help design possible future healthcare scenarios and facilitate decision-making on optimal healthcare allocation. However, there are two issues that should be taken into account when interpreting these population-based results. The first issue relates to differences in case definition and coding. For example, some countries base their fall-related injury rates solely on hospital admissions, whereas others take into account ED visits, as well. This can have a large effect on the total fall-related morbidity. In addition, the World Health Organization has published and revised several International Classification of Diseases (ICD) editions, since 1948 [1]. A fall can be classified in several ways, by using codes that are reported in the ICD editions. Inconsistencies in the use of codes between population-based data sources over time could influence results. The second issue relates to the availability of nationally representative data. In Chapter 2 of this thesis, GBD 2016 data on fall-related morbidity and mortality from 22 European countries is presented. Nationally representative data on falls was only available for five countries (Belgium, Finland, the Netherlands, Portugal, and Switzerland). In order to calculate the complete data on falls for the other countries, statistical models were used. Therefore, the estimates of countries without national representative data are less precise [2]. Of the 22 European countries, the Netherlands was the only country that provided data on fall-related ED visits. As explained in Chapter 3 of this thesis, the Netherlands has access to three reliable databases with an almost complete national coverage, to calculate fall-related ED visits, hospital admissions, and fatalities. If more countries would provide such data sources on falls, injury estimates of the GBD would greatly improve. Even though the Netherlands has access to data with an almost complete national coverage, the data is likely to represent serious fall-related injuries only, as minor fall-related injuries, treated at a general practitioner, are not taken into account. Therefore, the actual societal impact of all fall-related injuries might be even higher than depicted in Chapter 2 and 3.

Economically evaluating falls prevention interventions

Besides evaluating the effectiveness of a research intervention, it is important to gain insight into the cost-effectiveness, as well. This is also the case with studies evaluating falls prevention interventions. Unfortunately, it is sometimes difficult to interpret these economic evaluation studies, as described in Chapter 4 of the current thesis. A number of issues that need to be taken into account are presented here. First, even though guidelines for economic evaluations exist, that state the importance of clearly reporting economic evaluation methods [3, 4], few studies adhere to these guidelines. Specifically, studies differ in terms of reporting what health economic perspective was chosen (i.e. healthcare or societal), whether a baseline fall risk was determined, which cost categories were used (i.e. program, healthcare, or informal care costs), and how uncertainty was handled (i.e. sensitivity analyses). When these methods are not reported by a study, it is difficult to properly compare the results with another study. Second, the primary outcome measure of a cost-effectiveness analysis is the incremental cost-effectiveness ratio (ICER), of which QALYs are generally used as a generic utility measure. In order to compare the ICERs between studies, a willingness-to-pay (WTP) threshold is used. Even though a WTP of $50,000 per QALY gained is widely accepted in the United States [5], WTP values have no solid scientific basis [6]. The cost-effectiveness of an intervention drastically changes if a different threshold is used. As shown in Chapter 4, the cost-effectiveness of falls prevention interventions severely decreased when a lower threshold of $20,000 per QALY was applied. In this case, the majority of the reported ICERs were above the threshold. Conversely, the cost-effectiveness increased substantially when a higher threshold of $100,000 was applied. Third, publication bias in economic evaluations is potentially present, as these evaluations are less likely to be performed when an intervention is ineffective [7]. Therefore, the findings presented in Chapter 4 are expected to overestimate the cost-effectiveness of falls prevention interventions in general. One way in which this could be improved is if grant providers make it mandatory for researchers to publish on the effectiveness and cost-effectiveness of their intervention. Another possibility is to require all economic evaluation studies to register their cost-effectiveness analyses before the start of their intervention.

Community approach to falls prevention

As the Dutch government is keen on making sure older adults participate in society for as long as possible, an integrated approach, in which local communities are co-producers in healthcare, is increasingly becoming popular [8]. This approach promotes collaborations between different local partners in order to improve health and well-being of citizens. An integrated neighbourhood approach has recently been evaluated in the city of Rotterdam, in the Netherlands [9]. This study showed that providing care through such an approach is complex, as bottom-up initiatives are not always aligned properly with top-down strategies. A systematic review on the implementation of falls prevention interventions in a community setting also reports on the complexity of this process [10]. They state that lots of factors influence the implementation success, which makes it difficult to identify the most important determinant. Several papers have been published to help researchers identify the most important determinants of their study. For example, Fleuren et al. (2004) identified 50 determinants that could be important in the implementation process [11]. Fifty-seven other determinants were identified by Flottorp et al. (2013) [12]. The determinants were divided into several domains, such as socio-political factors, professional interactions, and the required facilities. These comprehensive checklists could be used by researchers designing, implementing, and evaluating interventions; however, it remains difficult to determine whether the implementation of an intervention was truly successful. Another challenge in a community approach to falls prevention are the low participation rates of older adults [13-15], which are often caused by physical barriers, such as mobility problems or poor health in general [16, 17]. Low participation rates were observed in Chapter 6 of the current thesis, as well. Even though many older adults were reached, relatively few enrolled in the study. Particularly indirect recruitment methods, such as press releases, and commercials broadcasted on a local television and radio channel, resulted in few enrolments. The older adults that did participate in the study might not be representative of the general older adult population. Namely, the participants were relatively old, female, and without a migration background. Ethnic minorities are often underrepresented in health research [18], but some studies have shown effective methods to recruit this population. By providing bilingual program information, and by facilitating partnerships with community organizations, recruitment of older adults with a migration background could be improved [19, 20].

Societal impact

The process of creating value from knowledge, by making it suitable for society is termed 'knowledge valorisation' [21]. The Dutch National Commission Valorisation has developed several valorisation indicators, which can be used to evaluate the societal impact of a University, research grant provider, or a commercial company [21]. However, it could be interesting to use these indicators to estimate the societal impact of the ***Houd ouderen op de been*** study (Chapter 6, 7, and 8). A number of valorisation indicators were present in the ***Houd ouderen op de been*** study. Specifically, several local stakeholders were actively involved in designing and conducting the study. This included healthcare professionals, older adult unions, and volunteers. Furthermore, knowledge was shared with these stakeholders through network meetings and newsletters. Two other indicators that were present in the study were non-scientific publications and public appearances. Publications included several press releases, and a paper in a Dutch journal on geriatric physiotherapy. In addition, the results of the study were shared through presentations and workshops, at community centres and conventions. Two indicators that were not present in the ***Houd ouderen op de been*** study were knowledge valorisation planning and budget. If valorisation would have been a clear part of the study planning and budget, the societal impact would arguably be higher. Even though it can be assumed that the study has resulted in some societal impact, it remains difficult to quantitatively rate this impact. At least it can be assumed that, when scientific knowledge is only shared in scientific journals, the societal impact is small. However, by making sure researchers share their knowledge on a broader level, such as in newspapers, websites, policy documents, workshops or conventions, the societal impact will likely increase.

Recommendations and implications for research

1. Make use of reliable data sources on falls.

Even though several European countries have population-based data available on falls, only few countries own nationally representative data. Data sources such as the Dutch Hospital Discharge Registry have an almost complete national coverage with data available for multiple decades. These available data make it possible to describe injury trends based on sex, age groups, injury diagnosis, and on location of injury. If more European countries would provide such accurate data sources, fall-related injury estimates would greatly improve, and better comparisons can be made between different countries. Another way to improve injury estimates is to take into account both minor and major fall-related injuries. Currently, most data sources include fall-related injuries treated at a hospital, whereas minor injuries treated at a general practitioner are not included. Taking into account these minor injuries would give a better overview of the actual societal impact of all fall-related injuries.

2. Design, conduct, and report economic evaluations according to current guidelines.

Despite the existence of guidelines for economic evaluations, few studies on falls adhere to these guidelines. In order to improve the quality of health-economic evidence and to increase the comparability between studies, future economic evaluations of falls prevention interventions should be designed, conducted, and reported in accordance with current guidelines. Amongst others, it is important for studies to clearly state the health economic perspective, baseline fall risk, cost categories, and sensitivity analyses. Furthermore, studies are preferred to use QALYs as generic utility measure to calculate the ICER, as WTP thresholds have been established. Though, WTP values have no solid scientific basis, and countries use different values, so it is best if studies calculate the cost-effectiveness of their intervention based on several thresholds (e.g. $20,000, $50,000, and $100,000).

3. Involve local, trusted healthcare providers in the recruitment of older adults.

Recruitment of older adults in exercise interventions is complex and challenging. When implementing falls prevention interventions in a community setting, it is important to take into account the experiences, problems, and preferences of older adults and healthcare providers. This makes it possible to tailor the implementation to specific neighbourhoods and to specific populations. Furthermore, in the recruitment of older adults, it is key to involve local healthcare providers. Particularly the general practitioner and community nurse should be involved as trusted individuals that are able to personally motivate their patients to participate in exercise interventions.

Recommendations and implications for policy and practice

1. Annually identify older adults at risk for falls.

As many older adults are at risk to fall, and many can benefit from a falls prevention intervention, it is important to structurally identify those individuals at risk for a fall. A two-question screening tool that can be used annually is the fall risk assessment [22, 23]. This assessment calculates an individual's fall risk, based on the history of falls and mobility problems. The assessment can be administered by a general practitioner, or by a practice/community nurse. If the assessment shows that no elevated fall risk is present, the assessment can be repeated the following year. However, if the assessment does show that an elevated fall risk is present, an appointment together with the general practitioner or practice/community nurse could be made for a more comprehensive assessment. Amongst others, this assessment could include a medication check, an eye exam, or a home assessment. Based on this assessment and in consultation with the older adult, a referral could be made to a local physiotherapist or occupational therapist, which offers a tailored falls prevention intervention.

2. Make an inventory of costs, benefits, and local initiatives before implementing falls prevention in a community setting.

When an organization decides to implement a falls prevention intervention in the community, it is important to first make a comprehensive inventory. This inventory should include the expected costs and benefits of the intervention. Erasmus MC, Vilans, and VeiligheidNL have developed a calculation tool, which could be used for this purpose [24]. This tool clearly presents the costs and benefits based on the population (age and number of individuals), the recruitment strategy, and on the falls prevention intervention. Furthermore, the inventory should include an overview of local initiatives. A good collaboration with local initiatives could be beneficial for the implementation process, as it could result in reaching more older adults and in working more efficiently. Another tool that can be used before implementing the intervention is an implementation checklist. Preferably, a checklist is used, based on scientific literature, that is easy to use, and that will guide in designing and conducting the intervention.

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Summary

General introduction

Falls among older adults have a large impact on healthcare demands and costs, and on the quality of life of older adults. Numerous evidence-based falls prevention interventions are available; however, there is a lack of knowledge on the cost-effectiveness of these interventions, and on the conditions for successful implementation in a community.

The ultimate aim of this thesis was to explore the impact and prevention of fall-related injuries among older adults. This was accomplished by focusing on three topics. Part I covered the burden of fall-related injury and mortality among older adults. In Part II, the cost-effectiveness of several falls prevention interventions was evaluated, and in Part III, we determined the conditions for successful implementation of falls prevention in a community setting. The aims of this thesis were threefold:

1. To describe the burden over time of fall-related injury and mortality among older adults;
2. To systematically evaluate the cost-effectiveness of falls prevention programs;
3. To determine the conditions for successful implementation of falls prevention in a community setting.

Part I: The burden of fall-related injury and mortality

Chapter 2 presents a study using the Global Burden of Disease (GBD) results on falls among adults aged ≥70 years in 22 European countries, from 1990 until 2016. On average, one in eight older adults sought medical treatment following fall-related injury. Between 1990 and 2016, there was considerable variation between countries in the fall-related incidence, burden of disease, and mortality. For example, between countries with the lowest and highest fall-related mortality, a fourfold difference in mortality rates was observed. In Chapter 3, the time trends of fall-related healthcare use and mortality among adults aged ≥65 years in the Netherlands, between 1997 and 2016 were described. In that time period, absolute numbers of fall-related Emergency Department (ED) visits increased by 48%, hospital admissions increased by 59%, and mortality showed an almost threefold increase. These increased numbers were particularly seen among adults aged ≥85 years. Even though the absolute number of fall-related ED visits increased, standardized incidence rates of ED visits decreased by 30%, over time. In addition, the absolute number of hospital admission days almost halved, due to a reduced average length of hospital stay from 18.5 days (1997) to 6.1 days (2016).

Part II: Cost-effectiveness of falls prevention

A systematic review on the cost-effectiveness of different falls prevention programs among adults aged ≥60 years was presented in Chapter 4. In total, 31 studies were included. The majority of falls prevention programs were considered cost-effective. Specifically, about two-thirds of all studies reported an incremental cost-effectiveness ratio (ICER) – with quality-adjusted life-years (QALY) as outcome – below a willingness-to-pay threshold of $50,000 per QALY. Home assessment programs were the most cost-effective program for community-dwelling older adults (ICER < $40,000/QALY), and medication adjustment programs were the most cost-effective program for older adults living in a residential care facility (ICER < $13,000/QALY). Even though there was variation in the methodological quality between studies, the average quality score was good (84%).

Part III: Falls prevention in a community setting

In Chapter 5, a two-round online Delphi study on the current falls prevention activities of Dutch healthcare professionals in a community setting was described. The Delphi panel consisted of a total of 125 health experts in the field of falls prevention. According to the panel, regular detection of older adults with a fall risk is rare, referral to falls prevention programs is lacking, and structural follow-up is hardly ever offered. In addition, older adults are reluctant to participate in annual detection of fall risk. Participation could be stimulated by a combination of national health education, healthcare counselling, and removal of financial barriers. The general practitioner, physiotherapist, and informal caregiver are considered key individuals in falls prevention activities. The implementation of a twelve-week home-based exercise program among adults aged ≥65 years was described and evaluated in Chapter 6. The implementation plan consisted of dialogues with healthcare professionals and older adults, development of an implementation protocol, recruitment of participants, program implementation, and implementation evaluation. The dialogues consisted of a Delphi survey among healthcare professionals, and individual and group meetings among older adults. In this study it was found that the negative consequences of a fall and positive effects of preventing a fall should be emphasized to older adults, in order to get them engaged in falls prevention activities. The implementation of the home-based exercise program was evaluated using the framework model RE-AIM. A total of 238 older adults participated in the program, of which the majority were recruited by a community nurse. Furthermore, a good collaboration between the research team and the local primary healthcare providers was accomplished, which was important in the recruitment of participants. Chapter 7 presented which factors were associated with frequent participation of older adults in the twelve-week home-based exercise program. Furthermore, the effects of frequent participation on health-related outcomes over time were presented. Frequent participation was classified as performing exercises of the program daily or a few days a week. In total, 52% of the participants frequently participated during the study period. A higher degree of pain (OR:1.02, 95% CI:1.00-1.04) was associated with frequent participation. In addition, the effect of frequent participation over time was a significant improvement in current health perceptions (B: 4.46, SE: 1.99). Chapter 8 presents a study in which nine different exercise-based falls prevention interventions were offered to adults (n=138) aged ≥65 years for twelve weeks. This study investigated the association between personal preferences, chosen falls prevention intervention, and participation rates. In general, one group (25%) of participants preferred to exercise at home, alone, and for free, whereas another group (26%) preferred to exercise at an external location, in a group, and for a fee. When the personal preferences of a participant were met, the participant was not more likely to frequently participate in the intervention.

General discussion

In Chapter 9, the main findings of Chapter 2 through 8 were described and interpreted. Furthermore, the methodological considerations 'data sources on falls', 'economically evaluating falls prevention interventions', 'community approach to falls prevention', and 'societal impact' were described. Based on the research presented in this thesis, the following recommendations and implications were presented:

Recommendations and implications for research

1. Make use of reliable data sources on falls.
2. Design, conduct, and report economic evaluations according to current guidelines.
3. Involve local, trusted healthcare providers in the recruitment of older adults.

Recommendations and implications for policy and practice

1. Annually identify older adults at risk for falls.
2. Make an inventory of costs, benefits, and local initiatives before implementing falls prevention in a community setting.

Samenvatting

Algemene introductie

Valpartijen bij ouderen hebben een grote invloed op de zorgvraag en –kosten, en op de kwaliteit van leven van ouderen zelf. Tal van bewezen effectieve valpreventie interventies zijn beschikbaar, maar er is een gebrek aan kennis over de kosteneffectiviteit van deze interventies, en over de voorwaarden voor een succesvolle implementatie in een wijksetting.
Het doel van dit proefschrift was om de impact en preventie van valgerelateerde letsels bij ouderen te onderzoeken. Dit werd bereikt door te focussen op drie onderwerpen. Deel I behandelde de last van valgerelateerde letsels en mortaliteit bij ouderen. In Deel II werd de kosteneffectiviteit van verschillende valpreventie interventies geëvalueerd. In Deel III hebben we de voorwaarden bepaald voor een succesvolle implementatie van valpreventie in een wijksetting. De doelstellingen van dit proefschrift zijn als volgt:

1. Het beschrijven van de (ziekte)last over meerdere jaren, van valgerelateerde letsels en mortaliteit bij ouderen;
2. Het systematisch evalueren van de kosteneffectiviteit van valpreventie programma's;
3. Het bepalen van de voorwaarden voor een succesvolle implementatie van valpreventie in een wijksetting.

Deel I: De (ziekte)last van valgerelateerde letsels en mortaliteit

Hoofdstuk 2 beschreef een studie waarbij data van de 'Global Burden of Disease' (GBD) wordt gebruikt over valpartijen bij ouderen (70+) in 22 Europese landen, tussen 1990 en 2016. Gemiddeld zochten 1 op de 8 ouderen medische hulp na een valpartij. Tussen 1990 en 2016 waren er grote verschillen tussen landen op het gebied van de valgerelateerde incidentie, ziektelast, en mortaliteit. Bijvoorbeeld, tussen landen met de laagste en hoogste valgerelateerde mortaliteit zat een verschil van factor vier. In Hoofdstuk 3 werden de trends in valgerelateerd zorggebruik en mortaliteit bij Nederlandse ouderen (65+), tussen 1997 en 2016, beschreven. In die tijdsperiode stegen de absolute aantallen valgerelateerde spoedeisende hulp (SEH) bezoeken (48%) en ziekenhuisopnamen (59%). De absolute valgerelateerde mortaliteit steeg met bijna een factor drie. De toegenomen aantallen zijn vooral zichtbaar bij personen ouder dan 85 jaar. Ondanks dat de absolute aantallen van valgerelateerde SEH bezoeken toenamen, nam de gestandaardiseerde incidentie de afgelopen twintig jaar met 30% af. Daarnaast is het totaal aantal valgerelateerde ligdagen bijna gehalveerd, vanwege een afname in de gemiddelde ligduur van 18,5 dagen (1997) naar 6,1 dagen (2016).

Deel II: Kosteneffectiviteit van valpreventie

Hoofdstuk 4 beschreef een systematische review over de kosteneffectiviteit van verschillende valpreventie programma's bij ouderen (60+). In totaal werden 31 studies opgenomen in de review. De meerderheid van de valpreventie programma's werden als kosteneffectief beschouwt. Twee derde van de studies vermeldde namelijk een incrementele kosteneffectiviteitsratio (IKER) – met ‘quality-adjusted life-years’ (QALYs) als uitkomst – onder de drempelwaarde van $50.000 per QALY. Programma’s waarbij huisaanpassingen werden gedaan, waren het meest kosteneffectief voor zelfstandig thuiswonende ouderen (IKER < $40.000/QALY). Programma’s waarbij medicatie aanpassingen werden gedaan, waren het meest kosteneffectief voor ouderen die niet zelfstandig thuiswonend waren (IKER <$13.000/QALY). Ondanks dat er variatie was in de methodologische kwaliteit tussen studies, de gemiddelde kwaliteit van studies was goed (84%).

Deel III: Valpreventie in een wijksetting

In Hoofdstuk 5 werd een Delphi studie over de huidige valpreventie activiteiten van Nederlandse zorgprofessionals beschreven. De studie bestond uit twee rondes van online vragenlijsten. Het Delphi panel bestond uit 125 experts op het gebied van valpreventie. Volgens het panel is de opsporing van ouderen met een verhoogd valrisico zeldzaam, worden weinig ouderen naar een valpreventie programma verwezen, en wordt follow-up na een programma nauwelijks aangeboden. Daarnaast zijn ouderen niet snel geneigd om deel te nemen aan een jaarlijkse valrisico screening. Een combinatie van voorlichting vanuit de overheid, advisering vanuit de zorg en het wegnemen van financiële belemmeringen voor de oudere wordt gezien als de meest effectieve methode om deelname te stimuleren. De huisarts, fysiotherapeut en mantelzorger worden gezien als belangrijke personen binnen de valpreventie. Hoofdstuk 6 beschreef de implementatie van een beweegprogramma dat twaalf weken lang bij Bredase ouderen (65+) thuis werd aangeboden. Het implementatie plan bestond uit het in gesprek gaan met zorgverleners en ouderen, het ontwikkelen van een implementatie protocol, de werving van deelnemers, het implementeren van het programma en het evalueren van het programma. In gesprek gaan met zorgverleners en ouderen bestond uit een Delphi enquête bij zorgprofessionals, en uit individuele- en groepsbijeenkomsten met ouderen. Uit die gesprekken kwam naar voren dat de negatieve consequenties van een val, en de positieve effecten van het voorkomen van een val benadrukt moeten worden bij ouderen om ervoor te zorgen dat ze betrokken willen worden bij valpreventie activiteiten. De implementatie van het beweegprogramma werd geëvalueerd aan de hand van het RE-AIM model. In totaal waren er 238 deelnemers bij het programma, waarbij de meerderheid geworven was door wijkverpleegkundigen. Een goede samenwerking tussen het onderzoeksteam en lokale zorgverleners was bewerkstelligd, wat belangrijk was bij de werving van deelnemers.

In Hoofdstuk 7 werden de factoren die geassocieerd zijn met frequente deelname in het beweegprogramma beschreven. Ook werd het effect van frequente deelname bij het programma op gezondheid gerelateerde uitkomsten beschreven. Frequente deelname werd geclassificeerd als dagelijks of een paar dagen per week oefeningen van het beweegprogramma doen. In totaal hebben 52% van de deelnemers frequent deelgenomen aan het programma, gedurende twaalf weken. Een hogere mate van pijn (OR:1,02; 95% CI:1,00-1,04) was geassocieerd met frequente deelname. Daarnaast zorgde frequente deelname voor een significant betere perceptie van de gezondheid (B: 4,46; SE: 1,99). Hoofdstuk 8 beschreef een studie waarbij negen verschillende beweegprogramma’s werden aangeboden aan 138 ouderen (65+), gedurende twaalf weken. De studie onderzocht de associatie tussen persoonlijk voorkeuren, gekozen beweegprogramma en mate van deelname. Over het algemeen konden er twee duidelijke groepen deelnemers onderscheiden worden. Eén groep deelnemers (25%) volgden bij voorkeur een programma thuis, alleen en gratis, en een andere groep deelnemers (26%) volgden bij voorkeur een programma op locatie, in een groep en tegen betaling. Als er rekening werd gehouden met de voorkeuren van een deelnemer was de kans niet groter dat de deelnemer frequent deelnam aan het beweegprogramma.

Algemene discussie

In Hoofdstuk 9 werden de belangrijkste bevindingen van Hoofdstuk 2 tot en met 8 beschreven en geïnterpreteerd. Verder werden de methodologische overwegingen 'databronnen over vallen', 'economisch evalueren van valpreventie interventies', wijkgerichte aanpak van valpreventie' en 'maatschappelijke impact' beschreven. Op basis van het onderzoek verricht in dit proefschrift werden de volgende aanbevelingen en implicaties gepresenteerd:

Aanbevelingen en implicaties voor onderzoek

1. Maak gebruik van betrouwbare databronnen over vallen.
2. Maak gebruik van huidige richtlijnen bij het ontwerpen, uitvoeren en rapporteren van economische evaluaties.
3. Betrek lokale, vertrouwde zorgverleners bij de werving van ouderen.

Aanbevelingen en implicaties voor beleid en praktijk

1. Identificeer jaarlijks welke ouderen een verhoogd valrisico hebben.
2. Maak een inventarisatie van de kosten, baten en lokale initiatieven voordat valpreventie wordt geïmplementeerd in een wijksetting.

List of publications

This thesis

Chapter 2: J. A. Haagsma, B. F. Olij, M. Majdan, E. F. van Beeck, S. James, T. Vos, and S. Polinder, "Falls in older aged adults in 22 European countries: incidence, mortality and burden of disease from 1990 to 2016," 2019. (submitted)

Chapter 3: B. F. Olij, M. J. M. Panneman, E. F. van Beeck, J. A. Haagsma, K. A. Hartholt, and S. Polinder, "Fall-related healthcare use and mortality among older adults in the Netherlands, 1997-2016," Experimental Gerontology, vol. 120, pp. 95-100, 2019.

Chapter 4: B. F. Olij, R. H. Ophuis, S. Polinder, E. F. van Beeck, A. Burdorf, M. J. M. Panneman, and C. S. Sterke, "Economic evaluations of falls prevention programs for older adults: A systematic review," Journal of American Geriatrics Society, vol. 66, pp. 2197-204, 2018.

Chapter 5: B. F. Olij, V. Erasmus, J. I. Kuiper, F. van Zoest, E. F. van Beeck, and S. Polinder, "Falls prevention activities among community-dwelling elderly in the Netherlands: A Delphi study," Injury, vol. 48, pp. 2017-2021, 2017.

Chapter 6: B. F. Olij, V. Erasmus, L. M. Barmentloo, A. Burdorf, D. Smilde, Y. Schoon, N. van der Velde, and S. Polinder, "Evaluation of implementing a home-based fall prevention program among community-dwelling older adults," International Journal of Environmental Research and Public Health, vol. 16, 2019.

Chapter 7: B. F. Olij, L. M. Barmentloo, D. Smilde, N. van der Velde, S. Polinder, Y. Schoon, and V. Erasmus, "Factors associated with participation of community-dwelling older adults in a home-based falls prevention program," International Journal of Environmental Research and Public Health, vol. 16, pp. 1087, 2019.

Chapter 8: L. M. Barmentloo, B. F. Olij, V. Erasmus, D. Smilde, Y. Schoon, and S. Polinder, "Personal preferences of participation in falls prevention programs," 2019. (submitted)

Other publications

B. F. Olij, S. Polinder, V. Erasmus, and D. Smilde, "Valpreventie-activiteiten bij ouderen in Nederland: Een Delphi-studie onder zorgverleners uit de eerste lijn," Nederlands Tijdschrift voor Geriatriefysiotherapie, vol. 32, pp. 31-37, 2018.

D. J. Boyne, D. E. O'Sullivan, B. F. Olij, W. D. King, C. M. Friedenreich, and D. R. Brenner, "Physical activity, global DNA methylation and breast cancer risk: A systematic literature review and meta-analysis," Cancer Epidemiology and Prevention Biomarkers, vol. 27, 2018.

R. H. Ophuis, B. F. Olij, S. Polinder, and J. A. Haagsma, "Prevalence of post-traumatic stress disorder and depression following violence related injury treated at the emergency department: a systematic review," BMC Psychiatry, vol. 18, 2018.

About the author

Branko Olij was born on June 8th, 1991 in Leidschendam, the Netherlands. In 2009, he completed secondary school at Veurs Lyceum in Leidschendam and started studying Nutrition & Health at Wageningen University. After obtaining a bachelor's degree in 2013, he obtained a master's degree on Nutrition & Health, with the specialization Epidemiology & Public Health in 2016. His thesis was titled 'Effect and process evaluation of a lifestyle intervention study for low socioeconomic individuals aimed at improving components of the metabolic syndrome (MetSLIM)'. In May 2016, he started his PhD research at the department of Public Health of the Erasmus MC in Rotterdam, which resulted in this thesis. In June 2019, Branko started working as a researcher/ data analyst for VeiligheidNL in Amsterdam.

Branko Olij werd geboren op 8 juni 1991 in Leidschendam. In 2009 behaalde hij zijn atheneum diploma aan het Veurs Lyceum te Leidschendam. Vervolgens begon hij aan zijn studie Voeding en Gezondheid aan de Wageningen Universiteit. Na de bachelor te hebben afgerond in 2013, behaalde hij zijn master diploma Voeding en Gezondheid in 2016, met de specialisatie Epidemiologie & Volksgezondheid. Zijn scriptie was getiteld 'Effect and process evaluation of a lifestyle intervention study for low socioeconomic individuals aimed at improving components of the metabolic syndrome (MetSLIM)'. In mei 2016 begon hij aan zijn promotie traject bij de afdeling Maatschappelijke Gezondheidszorg van het Erasmus MC te Rotterdam, wat resulteerde in dit proefschrift. Sinds juni 2019 is Branko werkzaam als onderzoeker/gegevensanalist bij VeiligheidNL in Amsterdam.

PhD portfolio

Name PhD student: Branko Olij
Department: Public Health
PhD period: May 2016 – May 2019
Promotor: Prof.dr.ir. A. Burdorf
Copromotoren: Dr. S. Polinder, Dr. V. Erasmus
ECTS: 36.3

1. PhD training	Year	ECTS
General courses		
- NIHES – Methods of Public Health Research	2016	0.7
- NIHES – Health Economics	2016	0.7
- GemsTracker	2016	0.2
- Time Management	2016	0.2
- Systematic Literature Retrieval and EndNote	2016	0.6
- BROK	2017	1.0
- NIHES – From Problem to Solution in Public Health	2017	0.6
- ME-TA economic evaluations	2017	0.7
- VeiligheidNL theme meeting falls prevention	2017	0.2
- Biomedical English Writing and Communication	2017-2018	3.0
- Scientific integrity	2018	0.3
- Ergo coach	2018	0.2
- Career event	2018	0.2
- Employability outside academia	2018	0.7
Seminars and workshops		
- Department of Public Health seminars	2016-2018	5.0
- FNO workshop – Reach study population	2017	0.2
- FNO workshop – Project leader meeting	2017	0.2
Oral presentations		
- European conference on injury prevention and safety promotion	2017	2.0
- VeiligheidNL theme meeting falls prevention	2017	1.0
- National fall symposium	2017	1.0
- GENERO steering group	2018	1.0
- GENERO workshop	2018	1.0
- EU Falls Festival	2018	2.0
- GGD Utrecht work table falls prevention	2018	1.0
- NVFG congress	2018	1.0
- Department of Public Health research seminar	2018	1.0
- FNO national congress (poster)	2018	1.0
- Section meeting	2018-2019	3.0
Conferences		
- National fall symposium	2016-2018	0.3
- EU Falls Festival	2017-2018	0.4

- Lowlands Health Economic Study Group	2017	0.2
- European conference on injury prevention and safety promotion	2017	0.2
- PhD day	2017	0.1
- GGD Utrecht work table falls prevention	2018	0.1
- NVFG congress	2018	0.1
- FNO national congress	2019	0.1
- Health Sciences Research Day	2019	0.1
2. Teaching		
- Supervising community projects	2017-2018	2.0
- Supervising Master's internship and thesis (Avans+)	2017-2019	2.0
- Lecturing 'Hoe houden we de zorg betaalbaar?'	2019	1.0

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