Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Influence of a Multifactorial Falls Prevention Programme on Injury-Related Health Care Utilization and Costs

Niko Jukka Einari Korpi

niko.korpi@helsinki.fi

University of Helsinki: Helsingin Yliopisto https://orcid.org/0000-0002-5857-7721

Merja K Laine

University of Helsinki: Helsingin Yliopisto https://orcid.org/0000-0002-1848-1514

Tomi Paavo Tuomas Korpi

University of Helsinki: Helsingin Yliopisto https://orcid.org/0009-0003-0217-8291

Hannu Kautiainen

Samfundet Folkhälsan: Samfundet Folkhalsan https://orcid.org/0000-0003-0786-0858

Marja Mikkelsson

University of Helsinki: Helsingin Yliopisto https://orcid.org/0000-0003-2215-5292

Research Article

Keywords: Falls prevention, Multifactorial intervention, Older adults, Health care utilization, Specialized health care, Health care costs

Posted Date: May 22nd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9606935/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Abstract

Purpose

Our study aims to retrospectively investigate injury-related specialized health care utilization and costs among primary health care patients participating in a multifactorial falls prevention programme (MFFP) compared with sex-, age-, and residence-matched population-based controls.

Methods

This is a Finnish single-centre observational, retrospective, register-based controlled cohort study including 527 community-dwelling primary health care MFFP patients and their 3:1 age-, sex-, and residence-matched population-based controls (n = 1581), who had not participated in the MFFP. Patients' injury-related specialized health care utilization was followed from their first MFFP visit until death or the end of December 2019.

Results

MFFP patients had more injury-related outpatient visits [IRR 1.76 (95% CI 1.63 to 1.91)] and hospitalizations [IRR 1.88 (95% CI 1.76 to 2.01)] than the controls. Among those with injury-related specialized health care utilization, the costs per person-year were not significantly higher than in controls for outpatient visits [mean ratio 1.06 (95% CI 0.71 to 1.58)], hospitalizations [mean ratio 1.03 (95% CI 0.68 to 1.56)], or total costs [mean ratio 1.11 (95% CI 0.74 to 1.67)]. MFFP patients did not accumulate higher total specialized health care costs than their controls.

Conclusion

MFFP patients had more injury-related specialized health care utilization than matched controls, but the total injury-related costs were similar between groups.

Key summary points

Aim:

To investigate injury-related specialized health care utilization and costs among primary health care patients participating in a multifactorial falls prevention programme compared with age-, sex-, and residence-matched population-based controls.

Findings:

Participants in the multifactorial falls prevention programme had higher injury-related specialized health care utilization than matched controls, reflecting their higher baseline risk. Despite this, total injury-related specialized health care costs were similar between the groups over long-term follow-up.

Message:

Among older adults at elevated fall risk, multifactorial falls prevention programmes may help contain specialized health care costs over time while addressing injury-related needs in a high-risk population.

Background

Globally, more than 700 to 900 million injuries occur annually, resulting in a substantial burden on individuals, health care systems, and national economies (1, 2). These injuries arise mainly from traffic injuries, unintentional injuries – including falls, drowning, and burns – as well as self-harm and interpersonal violence (1, 2). Among these, falls constitute the leading cause of injury-related hospitalizations worldwide, placing substantial pressure on health care systems through emergency department visits and hospitalizations (3–5). Most falls occur during leisure time and in home environments (3–5).

Older adults fall more frequently than younger individuals, and both the incidence and severity of fall-related injuries increase with age (3–6). It is estimated that 28–35% of individuals aged 65 years and older experience at least one fall each year worldwide (4). Fall risk in older adults arises from the interaction of multiple non-modifiable factors – such as increasing age, previous falls, and chronic diseases – and modifiable factors including polypharmacy, malnutrition, frailty, and lifestyle-related factors, many of which cluster in later life (7). Consequently, older adults often present with multimorbidity and functional decline that substantially elevate their risk of falls and fall-related injuries (2, 3).

In Finland, falls constitute a major cause of injury-related health care utilization. In 2018, they resulted in 62 648 hospitalizations, accounting for 60% of all injury-related admissions (5). Among Finnish adults aged 65 years or older, fall-related hospitalizations remained consistently high, averaging 24 189 annually between 2021 and 2023 (8). The overall burden of injuries is also considerable: in 2017, injury-related outpatient visits reached 470 000 nationwide, generating an estimated total cost of €160 million (5). International comparisons further highlight the scale of the issue, with average cost of fall-related injury hospitalizations among older adults ranging from USD 6646 in Ireland to USD 17 483 in the United States (4). Specialized health care accounts for the most severe and costly consequences of falls and constitutes the largest share of fall-related economic burden in most health care systems (6, 9). Previous research has also shown that injury- and fall-related health care costs are highly concentrated, with a relatively small proportion of individuals accounting for a large share of total expenditures (10–12).

A tailored, guided, and progressive multifactorial falls prevention programme (MFFP) has been previously shown to reduce the incidence of falls and fall-related injuries in several settings (13, 14). Conventional falls prevention programmes have also demonstrated cost-effectiveness, particularly among community-dwelling older adults (15). However, evidence supporting the cost-effectiveness of MFFPs remains limited and inconsistent (16, 17). Benefits appear to be the greatest among relatively healthier patients with sufficient functional reserve, whereas in frail and multimorbid populations, reductions in fall incidence may not necessarily translate into reduced utilization or costs of specialized health care (16, 17).

The MFFP (18) implemented in the primary health care of Lahti, the capital city of the Päijät-Häme region in Finland, was based on a successful Finnish MFFP previously shown to prevent falls and fall-related injuries in the cities of Lappeenranta and Tampere (13). Participation in the the Lahti MFFP has also been associated with reduced all-cause mortality compared with their age-, sex-, and residence-matched controls (19).

This study aims to retrospectively investigate injury-related specialized health care utilization and costs among primary health care patients participating in a MFFP compared with their sex-, age-, and residence-matched population-based controls.

Materials and methods

This was a single-centre, observational retrospective, register-based controlled cohort study conducted in the city of Lahti, Finland. Lahti is a city in Southern Finland with approximately 121 000 inhabitants. A total of 527 primary health care MFFP patients included in this study represent all individuals who completed the MFFP in Lahti between January 2010 and December 2016. Patients that discontinued the MFFP were excluded from the analyses. All participants in the MFFP received an individualized exercise plan and medication review as part of the MFFP. Adherence to the individual exercise plans could not be assessed or quantified, as the medical records used for this study did not contain information whether or to what extent MFFP patients followed prescribed exercises. The MFFP has been described in detail in previous studies (18, 19). Follow-up extended from each patient's first MFFP visit (index date) until death or 31 December 2019, whichever occurred first. The same follow-up rules were applied to matched controls. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (20).

During the MFFP, patients at increased risk of osteoporosis, falling, and fall-related injuries were identified and treated within the local primary health care system in Lahti. Standard falls prevention and osteoporosis care in Lahti were coordinated by specially trained nurses at local primary health care centres. Referrals to the MFFP were made by primary and specialized health care nurses and physicians based on clinical judgment. Patients were referred to the MFFP if they had multimorbidity and functional impairments that compromised their ability to live independently (18). Notable multimorbidity included, for example, indeterminate cognitive impairment, Alzheimer's disease, Parkinson's disease, diabetes, and

cerebrovascular disorder (18). Relevant functional impairments included a history of falls, poor physical fitness, perceived frailty, height loss, kyphosis, balance disorders, and observable limitations in activities of daily living (18). There was no automatic screening or population-level referral pathway (18). This study focuses exclusively on injury-related specialized health care utilization and costs to ensure a precise and clinically relevant evaluation of the MFFP's impact. Specialized care reflects the most severe and costly consequences of falls and provides consistent registry data (21).

A trained study assistant extracted manually individual-level information for MFFP patients – such as multimorbidity, functional status and referral criteria from the MFFP patient documentations in the primary health care electronic medical records. The background variables (Table 1) were selected because they were consistently available and systematically recorded for all MFFP patients in the electronic medical records. Smoking was noted if the patient was smoking at the time of the MFFP. Previous history of smoking was not acknowledged. Alcohol consumption was categorized into two levels: none or use. The records did not contain systematic documentation of adherence to the exercise plans or injury mechanisms, which therefore could not be collected.

Table 1
Characteristics of the multifactorial falls prevention programme patients (N = 527) from the city of Lahti, Finland.

Characteristic	**Women**	**Men**	**All**
	n = 473	**n = 54**	**N = 527 [n]***
Age, years, mean (SD)	76 (8)	78 (9)	77 (8) [527]
Body mass index, kg/m^2, mean (SD)	26.7 (5.0)	26.8 (4.6)	26.7 (4.9) [494]
Smokers, n (%)	32 (7)	6 (13)	38 (8) [493]
Alcohol use, n (%) **	179 (41)	23 (48)	207 (42) [484]
Diabetes, n (%)	53 (11)	12 (22)	65 (12) [527]
Alzheimer's disease, n (%)	23 (5)	3 (6)	26 (5) [527]
Cerebrovascular disease, n (%)	48 (10)	11 (20)	59 (11) [527]
Self-reported health, n (%)			[490]
Good/Excellent	91 (21)	9 (18)	100 (20)
Moderate	264 (60)	29 (59)	293 (60)
Poor	86 (20)	11 (22)	97 (20)
History of falling, n (%)	337 (76)	39 (80)	376 (76) [494]
Self-reported balance disorder, n (%)	316 (71)	46 (90)	362 (73) [494]
History of fractures, n (%)	323 (73)	28 (57)	351 (71) [493]
Unable to walk or difficulty in walking 500 m, n (%)	185 (42)	30 (60)	215 (44) [491]
Five times sit to stand test, s, mean (SD)	19.5 (11.4)	20.1 (11.1)	19.5 (11.3) [489]
*Number of those of whose information was available			

For each MFFP patient, three (3:1) population-based controls (n = 1581) were identified, based on age, sex, and place of residence (Lahti). The controls were identified using the registers of the Digital and Population Data Services Agency (DVV). The controls were assigned the same index date as the patient's first MFFP visit. Thus, follow-up for controls began on the corresponding case patient's MFFP visit date and continued until death or the end of December 2019, whichever came first. The controls were drawn from the same population but had not participated in the MFFP. Both groups belonged to the same health care system and received services from the same health care provider.

All injury-related specialized health care data (outpatient visits, hospitalizations and their ICD-10 diagnoses) were obtained electronically using a bulk extraction query from the medical records used in the regional specialized health care services of Päijät-Häme. These records included information on

injury-related specialized health care utilization for both MFFP patients and controls. Injury-related outpatient visits and hospitalizations were tracked from the date of each patient's first MFFP visit until the end of 2019 or death, whichever occurred first. In the regional specialized health care medical electronic medical records used in this study, all emergency department encounters and other specialized outpatient visits are recorded under the same outpatient visit category. The cases and controls were linked to their injury-related outpatient visit and hospitalization records, classified according to the International Classification of Diseases and Related Health Problems, 10th Revision (ICD-10: S00-S99, T00-T14) (22). Although external cause codes (W00-W19) were available in the registry data, they were recorded for only a small proportion of injury-related outpatient visits. Therefore, injury mechanisms could not be reliably classified, and analyses were based on injury-related diagnoses (S00-T14) rather than fall-specific encounters. This limitation applied equally to both groups and therefore primarily affects specificity rather than internal validity. Diagnosis-specific information for outpatient visits was available and is presented in Table 2. For hospitalizations, the registry data included reliable information on the presence and frequency of injury-related admissions and hospital days. The Finnish Hospital Discharge Register gathers patient information and has been found to be reliable according to the completeness and accuracy of the register (21). This high overall accuracy of Finnish specialized health care coding applies to the data system used in Päijät-Häme. The costs associated with diagnosis-based outpatient visits and hospitalizations were derived from the regional specialized health care provider's financial administration, using actual patient-level average diagnosis-specific cost weights (not national DRG tariffs). All costs were adjusted to the 2023 price level.

Table 2
Injury-related specialized health care utilization among multifactorial falls prevention programme patients compared with age-, sex-, and residence-matched population-based controls.

	Controls N = 1581 Incidence, (SE)*	Patients N = 527 Incidence, (SE)*	IRR (95% CI) **	Fall-related causes W00-W19	
				Controls N = 1581 N (%***)	Patients N = 527 N (%***)
Outpatient visit diagnoses (ICD-10)					
Injuries to the head (S00-09)	31.2 (2.0)	70.8 (4.9)	2.27 (1.89 to 2.73)	37 (15)	23 (11)
Injuries to the neck (S10-19)	1.6 (0.4)	9.9 (1.8)	6.22 (3.23 to 11.97)	1 (8)	1 (3)
Injuries to the thorax (S20-29)	6.0 (0.9)	17.4 (2.4)	2.90 (1.96 to 4.30)	6 (12)	1 (2)
Injuries to the abdomen, lower back, lumbar spine, and pelvis (S30-39)	9.9 (1.1)	14.4 (2.2)	1.45 (1.00 to 2.10)	6 (7)	5 (12)
Injuries to the shoulder and upper arm (S40-49)	20.2 (1.6)	41.4 (3.8)	2.05 (1.62 to 2.59)	20 (12)	8 (7)
Injuries to the elbow and forearm (S50-59)	26.5 (1.8)	43.8 (3.9)	1.65 (1.33 to 2.06)	16 (7)	1 (1)
Injuries to the wrist and hand (S60-69)	7.6 (1.0)	25.0 (2.9)	3.28 (2.34 to 4.61)	3 (5)	3 (4)
Injuries to the hip and thigh (S70-79)	50.9 (2.5)	59.9 (4.5)	1.18 (0.99 to 1.40)	36 (9)	25 (14)
Injuries to the knee and lower leg (S80-89)	28.8 (1.9)	49.3 (4.1)	1.71 (1.39 to 2.10)	11 (5)	7 (5)

* Average number with standard error (SE) of Injury-related specialized health care per 1000 patient-years.

** Incidence rate ratio between patients and controls.

***Percentage of all visits in the diagnostic group with recorded fall-related external cause code (W00-W19).

	Controls N = 1581 Incidence, (SE)*	Patients N = 527 Incidence, (SE)*	IRR (95% CI) **	Fall-related causes W00-W19	
				Controls N = 1581 N (%***)	Patients N = 527 N (%***)
Injuries to the ankle and foot (S90-99)	8.3 (1.0)	8.2 (1.7)	0.98 (0.62 to 1.57)	2 (3)	4 (17)
Injuries involving multiple or unspecified body regions (T00-14)	1.7 (0.5)	1.7 (0.8)	1.00 (0.36 to 2.77)	2 (9)	0 (0)
Total	193.9 (4.9)	342.1 (10.8)	1.76 (1.63 to 1.91)	140 (9)	78 (8)
Hospitalizations	263.5 (5.7)	495.0 (13.0)	1.88 (1.76 to 2.01)	..	..
* Average number with standard error (SE) of Injury-related specialized health care per 1000 patient-years.					
** Incidence rate ratio between patients and controls.					
***Percentage of all visits in the diagnostic group with recorded fall-related external cause code (W00-W19).					

The study was approved by the patient register holder of the Päijät-Häme Central Hospital District, Finland. The study adhered to the national Data Protection Act (1050/2018) [41] and the EU General Data Protection Regulation (GDPR) (23). Ethics committee approval was not required, as this was a register-based study and no patients were contacted.

Statistical analyses

We present continuous variables using mean and standard deviation (SD) and categorical variables using frequency and percentage. We calculated the incidence of injury-related specialized health care utilization estimates (per 1000 person-years) and the corresponding incidence rate ratios (IRR) using Poisson regression or logistic models, depending on which method was most appropriate. Poisson models goodness-of-fit was assessed using deviance and Pearson chi-squared tests, showing a good fit in all models. The cost data will be modelled using generalized gamma regression, which is a generalized linear model (GLM) with a log link and a gamma family. Gamma regression is a popular statistical model for skewed distributions, such as hospital cost data, or for data that can only take on positive values. The choice of Gamma distribution and log link was confirmed by the modified Park's

test. Because of the strongly right-skewed distribution of the costs with an excess of zeros, a hurdle model was applied to evaluate the expected cost. Hurdle-count models are 2-component models with a truncated count component for positive counts. The logit component was used to predict zero costs, and the second component was obtained by applying a GLM, and this was used to estimate the conditional expectation. A possible non-linear relationship between injury-related outpatient visits and age was assessed by using a 3-knot-restricted cubic spline Poisson regression model; knot locations are based on Harrell's recommended percentiles. Stata 17.0 (StataCorp LP; College Station, TX, USA) statistical package was used for the analysis.

Results

Table 1 shows the characteristics of the MFFP patients (n = 527). The mean age of MFFP patients was 77 years (SD 8), ranging from 45 to 96 years. Of the patients, 10% were men, 8% were smokers, and 42% reported alcohol use. A minority had the following chronic diseases: 12% had diabetes, 5% had Alzheimer's disease, and 11% had a history of stroke. Self-reported health was reported as excellent by 20% of patients, moderate by 60%, and poor by 20%. A history of previous falls was reported by 76% of patients, and 71% had experienced fractures. Self-reported balance difficulties were common (73%), and 44% of patients were either unable to walk or had difficulty walking 500 metres.

Table 2 compares injury-related specialized health care utilization between MFFP patients and controls, expressed per 1000 patient-years. MFFP patients had more outpatient visits [IRR 1.76 (95% CI 1.63 to 1.91)] and hospitalizations [IRR 1.88 (95% CI 1.76 to 2.01)] than controls. However, MFFP patients did not have a higher risk of outpatient visits due to injuries involving the hip and thigh, ankle and foot, or multiple body regions. External cause codes indicating falls (W00-W19) were recorded for a small minority of injury-related outpatient visits, comprising 9% of such visits among controls and 8% among MFFP patients. The low and similar proportion of fall-coded visits in both groups precluded reliable fall-specific analyses.

Mean injury-related specialized health care costs for MFFP patients were €2189 per person-year (95% CI 1499 to 2880), compared with €1175 per person-year (95% CI 837 to 1513) for controls, yielding a mean cost ratio of 1.86 (95% CI 0.92 to 2.65).

Table 3 shows injury-related specialized health care utilization and costs per patient-year for MFFP patients and controls. Of all participants, 52% of MFFP patients and 31% of controls had at least on injury-related outpatient visit, and 25% of MFFP patients and 14% of controls experienced at least one injury-related hospitalization. Similarly, 53% of MFFP patients and 32% of controls generated any injury-related specialized health care costs (Table 3.).

Table 3
Injury-related specialized health care utilization and costs among multifactorial falls prevention programme patients compared with age-, sex-, and residence-matched population-based controls using a hurdle methodology.

	Logit Portion[1]			GLM Portion[2] (per patient-years)		
	N (%)	**OR (95% CI)**	**P-value**	**Mean (95% CI) €***	**Mean Ratio (95% CI)**	**P-value**
Outpatient visits		2.41 (1.97 to 2.94)	< 0.001		1.06 (0.71 to 1.58)	0.76
Patients	276 (52)			274 (182 to 365)		
Controls	496 (31)			257 (201 to 313)		
Hospitalizations		2.10 (1.65 to 2.67)	< 0.001		1.03 (0.68 to 1.56)	0.88
Patients	134 (25)			3742 (2590 to 4894)		
Controls	221 (14)			3625 (2628 to 4623)		
Total		2.46 (2.01 to 3.00)	< 0.001		1.11 (0.74 to 1.67)	0.61
Patients	281 (53)			2053 (1436 to 2670)		
Controls	502 (32)			1850 (1341 to 2360)		

[1]Logit portion: considers the factor's relationship with the incidence of costs (i.e. cost > €0), shown with OR.

[2] GLM portion: considers the factor's relationship with costs (when the cost > €0)

* Per patient-years

MFFP patients had a significantly higher risk of accumulating more injury-related specialized health care utilization: outpatient visits [OR 2.41 (95% CI 1.97 to 2.94)], hospitalizations [OR 2.10 (95% CI 1.65 to 2.67)], and total utilization [OR 2.46 (95% CI 2.01 to 3.00)].

Among those who utilized injury-related specialized health care services, the person-year costs were not significantly higher for MFFP patients than for controls, for outpatient visits [mean ratio 1.06 (95% CI 0.71 to 1.58)], hospitalizations [mean ratio 1.03 (95% CI 0.68 to 1.56)], or total costs [mean ratio 1.11 (95% CI 0.74 to 1.67)].

MFFP patients had more specialized health care outpatient visits at younger ages than controls (Fig. 1). They also had more hospitalizations, and the incidence rate ratio differed across age groups with a significantly higher incidence rate that was age-dependent (Fig. 2). However, MFFP patients did not accumulate higher total injury-related specialized health care costs than controls. In both groups, the inflection points for total costs occurred at the 80th percentile (Fig. 3).

Discussion

Main findings and interpretation

The present study showed that injury-related specialized health care utilization was higher among MFFP patients than among matched population-based controls, whereas total injury-related specialized health care costs were broadly similar between the two groups. MFFP patients experienced more outpatient visits at younger ages and more hospitalizations, with utilization patterns varying by age. Importantly, in both groups, a relatively small proportion of individuals accounted for the majority of total injury-related specialized health care costs.

Comparison with previous evidence

The higher level of injury-related specialized health care utilization observed among MFFP patients is consistent with prior literature emphasizing that injuries and falls disproportionately affect individuals with multiple interacting risk factors (7). Older adults often accumulate both non-modifiable risk factors – such as advanced age, chronic neurological and cardiovascular conditions, and previous falls – and modifiable factors including polypharmacy, frailty, malnutrition, depression, and alcohol use (2,7). The MFFP patients in the present study represented a clinically selected, high-risk population in whom many of these risk factors co-occurred, providing a plausible explanation for their higher utilization of injury-related specialized health care services.

Health care expenditure is known to be highly concentrated, with a small proportion of individuals generating a disproportionately large share of overall costs (12). This pattern has also been demonstrated specifically for injury- and fall-related health care costs (10,11). Our findings align closely with this evidence: although injury-related utilization was more frequent among MFFP patients, most costs in both groups were generated by a limited subset of individuals. Moreover, among those who used specialized health care services, costs per person-year were not significantly higher in the MFFP group, suggesting that increased utilization did not translate into disproportionate economic burden at the individual level.

Accumulating evidence indicates that MFFP can reduce falls and fall-related injuries in some populations (13,14,24). However, results regarding their impact on hospital admissions, injuries requiring medical attention, and health care costs have been inconsistent (14,25). Additionally, recent studies suggest that single-component exercise-based interventions may be equally effective, or even superior,

to MFFPs in reducing falls (26), while multifactorial approaches have not consistently demonstrated additional benefits in terms of costs, quality of life, or injury prevention (27).

Cost-effectiveness analyses further suggest that MFFPs may offer the greatest economic benefit among healthier adults with adequate functional reserve (17). In contrast, evidence remains limited among frail and multimorbid populations, in whom prevention of falls does not necessarily lead to reduced use of specialized health care services (16,17). Within this context, the present findings are not unexpected. The MFFP was implemented among individuals already identified as having elevated baseline risk, and it benefits may have manifested in a way not directly captured by injury-related specialized health care utilization or costs.

Notably, injuries to the hip, thigh, ankle, and foot – commonly associated with falls and osteoporosis – did not result in higher outpatient visit rates among MFFP patients compared with controls. One plausible explanation is that the MFFP may have reduced the severity of such injuries or facilitated earlier detection and management. Alternatively, similar injury patterns may have occurred in both groups despite differences in baseline risk, or injury-related utilization among MFFP patients may have been even higher in the absence of the intervention.

Injury-related health care utilization and costs increase with age, largely driven by falls and other unintentional injuries (3–6). Over long follow-up periods, injury-related events are likely to occur in most older adults (2,3,5). Consequently, comparable cumulative costs between MFFP patients and controls may reflect the long-term accumulation of injury events rather than short-term effects of preventive interventions. From a health system perspective, these findings suggest that expectations of immediate reductions in specialized health care cost from MFFPs targeted at frail and multimorbid populations may be unrealistic. Instead, the value of such programmes may lie in outcomes such as preserved functional independence, safer living at home, and delayed institutionalization, which have been associated with MFFP or exercise-based fall prevention interventions in previous studies (15,24). Reduced mortality has also been observed among participants in the Lahti MFFP (19). These are benefits that extend beyond direct cost savings.

Strengths and limitations

This study has several important strengths. It was conducted in a real-world primary health care setting and included individuals at elevated risk of falls, representing the population most commonly targeted by MFFPs. The use of sex-, age-, and residence-matched population-based controls from the same area strengthens internal validity by reducing bias related to regional health care organization and access to services.

A major strength is the use of comprehensive, region-wide registry data on injury-related specialized health care utilization and costs. These data are known to be highly reliable in Finland (21) and allowed complete, long-term follow-up from the index date until death or the end of 2019. The extended follow-up

period supports robust estimation of cumulative injury-related outcomes and reduces the influence of short-term variation.

This study focused specifically on injury-related specialized health care utilization and costs, which reflect most severe and resource-intensive consequences of injuries. Outcomes were captured using standardized ICD-10 diagnosis codes covering the entire region, minimizing under-reporting. Cost estimates were based on actual patient-level, diagnosis-specific cost weights from the regional specialized health care provider and adjusted to a common price level, enhancing the accuracy and relevancy of the economic evaluation.

Several limitations should be considered when interpreting the findings. First, the retrospective observational design does not allow causal inference. MFFP patients constituted a clinically selected, high-risk group referred based on professional judgement, and residual confounding related to baseline health status, multimorbidity, and functional capacity could not be fully addressed. Frailty, an important determinant of both falls and health care utilization, was not systematically assessed or recorded and therefore could not be included in the analyses, which may have biased estimates toward higher utilization in the MFFP group.

Second, although external cause codes are in principle available in Finnish health care registers, they were recorded for only a small proportion of injury-related outpatient visits in this study's data. As shown in Table 2, fall-related external cause codes accounted for less than 10% of injury-related visits in both groups, limiting the feasibility of fall-specific analyses. This limitation applied equally to MFFP patients and controls and is therefore unlikely to have affected the internal validity of between-group comparisons.

Third, injuries treated exclusively in primary care settings and post-acute rehabilitation provided in primary care wards were not captured. Therefore, the results should be interpreted as estimates of injury-related specialized health care burden rather than total health system burden. Additionally, registry data for the control group lacked information on morbidity, functional status, lifestyle factors, and frailty, limiting further risk adjustment. Adherence to the intervention could not be assessed, as information on compliance with prescribed exercise was not systematically documented.

Finally, the relatively small proportion of men among MFFP patients may limit the generalizability of the findings, particularly to older male populations. Injury-related specialized health care utilization occurring outside the regional specialized health care system or abroad was also no captured, although this limitation applied to both groups.

Future research

Future studies should address these limitations using prospective designs with standardized assessments of frailty, functional status, and fall risk at baseline. Comparison strategies that include

control groups with similar risk profiles, such as older primary health care patients with elevated fall risk from non-participating communities, would allow more refined estimates of MFFP effects. Pre- and post-intervention analyses and evaluation on injury-related utilization as proportion of total health care use may further clarify the contribution of falls prevention programmes to health care burden. Randomized controlled trials are ultimately needed to evaluate the effectiveness of MFFPs in reducing injury-related specialized health care utilization and costs, particularly among frail and multimorbid populations.

Conclusions

Although injury-related specialized health care utilization was higher among the primary health care MFFP patients than among controls, total costs were similar in both groups. MFFP patients had more specialized health care outpatient visits at younger ages and experienced more age-dependent hospitalizations than their controls. In both groups, most costs were generated by a small portion of individuals.

Declarations

We are submitting the original version of the study “Influence of a Multifactorial Falls Prevention Programme on Injury-Related Health Care Utilization and Costs" to be considered for publication in the European Geriatric Medicine. The manuscript has not been and will not be submitted, in part or entirety, elsewhere for publication. No other submissions or publications include material that is largely duplicative of that presented in the manuscript or derived from the same subjects. If accepted, the paper will not be published elsewhere in the same form, in English or in any other language, including electronically, without the written consent of the copyright holder.

All authors meet the criteria for authorship stated in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals. All authors conceived of the presented idea and developed the theory and Hannu Kautiainen performed the computations. Niko Korpi wrote the manuscript with input from all authors. Marja Mikkelsson supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

This research was supported by the Finnish Cultural Foundation, The Hospital District of Helsinki and Uusimaa and Päijät-Häme Joint Authority for health and wellbeing. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper. Large Language Models were not used in content creation.

On behalf of all co-authors, I would like to take this opportunity to thank the Editorial Boards for considering our paper. We sincerely hope that the study paper will be accepted for publication in the European Geriatric Medicine.

Acknowledgements

The authors thank the staff of the MFFP, particularly Iiris Salomaa, MASc, for their work in clinical interventional. We also extend our thanks to the financial controllers of the Wellbeing Services County of Päijät-Häme, especially Satu Siikaniemi, BASc, for collecting the specialized health care cost data. For financial support, we thank the Finnish Cultural Foundation and the Competitive State Research Financing of the Expert Responsibility area of the Hospital District of Helsinki and Uusimaa and Wellbeing Services County of Päijät-Häme. AI tools were not used in content creation or for English language improvement.

This study was financially supported partly by the Competitive State Research Financing of the Expert Responsibility area of The Hospital District of Helsinki and Uusimaa and Wellbeing services County of Päijät-Häme, Grant number 30030. Niko Korpi has received a personal research grant from the Finnish Cultural Foundation, Grant number 70251806.

Declaration of interest statement

On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Malekpour MR, Rezaei N, Azadnajafabad S, Khanali J, Azangou-Khyavy M, Moghaddam SS, et al. Global, regional, and national burden of injuries, and burden attributable to injuries risk factors, 1990 to 2019: results from the Global Burden of Disease study 2019. Public Health. 2024 Dec 1;237:212–31.
2. James SL, Lucchesi LR, Bisignano C, Castle CD, Dingels Z V., Fox JT, et al. The global burden of falls: global, regional and national estimates of morbidity and mortality from the Global Burden of Disease Study 2017. Inj Prev [Internet]. 2020 [cited 2023 Dec 20];26(Supp 1). Available from: https://pubmed.ncbi.nlm.nih.gov/31941758/
3. WHO. Step Safely - Strategies for preventing and managing falls across the life-course. Step Saf [Internet]. 2021 [cited 2025 Mar 15];4–38. Available from: https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/step-safely
4. WHO. WHO Global Report on Falls Prevention in Older Age : Prevention in Older Age. 2007;53.
5. Korpilahti U, Koivula R, Doupi P, Jakoaho V. Safely at All Ages : Programme for the Prevention of Home and Leisure Injuries 2021–2030. 2021 May 21 [cited 2022 Jan 19]; Available from: https://julkaisut.valtioneuvosto.fi/handle/10024/163155
6. Heinrich S, Rapp K, Rissmann U, Becker C, König HH. Cost of falls in old age: a systematic review. Osteoporos Int [Internet]. 2010 Jun [cited 2023 Dec 20];21(6):891–902. Available from: https://pubmed.ncbi.nlm.nih.gov/19924496/

7. Xu Q, Ou X, Li J. The risk of falls among the aging population: A systematic review and meta-analysis. Front Public Heal [Internet]. 2022 Oct 17 [cited 2026 Jan 30];10. Available from: https://pubmed.ncbi.nlm.nih.gov/36324472/
8. THL. Injury-related Hospitalizations 2021-2023 [Internet]. 2024 [cited 2025 Sep 5]. Available from: https://thl.fi/aiheet/hyvinvoinnin-ja-terveyden-edistamisen-johtaminen/turvallisuuden-edistaminen/tapaturmien-ehkaisy/tapaturmat-suomessa/tapaturmien-vuodeosastohoito
9. Kalman NS, Hammill BG, Schulman KA, Shah BR. Hospital overhead costs: the neglected driver of health care spending? journalofhealthcarefinance.comN Kalman, B Hammill, K Schulman, B ShahJournal Healthc Financ 2015•journalofhealthcarefinance.com [Internet]. 2015 [cited 2026 Mar 4]; Available from: https://journalofhealthcarefinance.com/index.php/johcf/article/view/27
10. Davis JC, Robertson MC, Ashe MC, Liu-Ambrose T, Khan KM, Marra CA. International comparison of cost of falls in older adults living in the community: a systematic review. Osteoporos Int 2010 218 [Internet]. 2010 Feb 27 [cited 2026 Apr 17];21(8):1295–306. Available from: https://link.springer.com/article/10.1007/s00198-009-1162-0
11. Florence CS, Bergen G, Atherly A, Burns E, Stevens J, Drake C. The Medical Costs of Fatal Falls and Fall Injuries among Older Adults. J Am Geriatr Soc [Internet]. 2018 Apr 1 [cited 2026 Apr 17];66(4):693. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6089380/
12. Cohen SB. The Concentration and Persistence in the Level of Health Expenditures over Time: Estimates for the U.S. Population, 2011-2012. Stat Br (Medical Expend Panel Surv [Internet]. 2001 [cited 2026 Apr 13]; Available from: http://www.ncbi.nlm.nih.gov/pubmed/29281227
13. Palvanen M, Kannus P, Piirtola M, Niemi S, Parkkari J, Järvinen M. Effectiveness of the Chaos Falls Clinic in preventing falls and injuries of home-dwelling older adults: a randomised controlled trial. Injury [Internet]. 2014 Jan [cited 2023 Dec 20];45(1):265–71. Available from: https://pubmed.ncbi.nlm.nih.gov/23579066/
14. Hopewell S, Copsey B, Nicolson P, Adedire B, Boniface G, Lamb S. Multifactorial interventions for preventing falls in older people living in the community: a systematic review and meta-analysis of 41 trials and almost 20 000 participants. Br J Sports Med [Internet]. 2020 Aug 21 [cited 2025 Feb 8];54(22):1340–50. Available from: https://pubmed.ncbi.nlm.nih.gov/31434659/
15. Olij BF, Ophuis RH, Polinder S, van Beeck EF, Burdorf A, Panneman MJM, et al. Economic Evaluations of Falls Prevention Programs for Older Adults: A Systematic Review. J Am Geriatr Soc [Internet]. 2018 Nov 1 [cited 2025 Mar 15];66(11):2197–204. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/jgs.15578
16. Alipour V, Azami-Aghdash S, Rezapour A, Derakhshani N, Ghiasi A, Yusefzadeh N, et al. Cost-Effectiveness of Multifactorial Interventions in Preventing Falls among Elderly Population: A Systematic Review. Bull Emerg trauma [Internet]. 2021 Oct [cited 2025 Mar 15];9(4):159–68. Available from: https://pubmed.ncbi.nlm.nih.gov/34692866/
17. Matchar DB, Eom K, Duncan PW, Lee M, Sim R, Sivapragasam NR, et al. A Cost-Effectiveness Analysis of a Randomized Control Trial of a Tailored, Multifactorial Program to Prevent Falls Among

the Community-Dwelling Elderly. Arch Phys Med Rehabil [Internet]. 2019 Jan 1 [cited 2025 Mar 15];100(1):1–8. Available from: https://pubmed.ncbi.nlm.nih.gov/30165053/

18. Salomaa I. Osteoporoosipotilaan tutkimus-, hoito- ja kuntoutusmallin kehittäminen ja prosessien mallintaminen : Lahden kaupungin sosiaali- ja terveystoimialalla. 2015 [cited 2023 Dec 20]; Available from: http://www.theseus.fi/handle/10024/101891
19. Korpi N, Mikkelsson M, Korpi T, Kautiainen H. The influence of the multifactorial falls prevention programme on mortality. Scand J Public Health [Internet]. 2024 Dec 5 [cited 2025 Jan 28]; Available from: https://journals.sagepub.com/doi/full/10.1177/14034948241285559
20. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol [Internet]. 2008 Apr [cited 2026 Mar 13];61(4):344–9. Available from: https://pubmed.ncbi.nlm.nih.gov/18313558/
21. Sund R. Quality of the Finnish Hospital Discharge Register: A systematic review. Scand J Public Health [Internet]. 2012 [cited 2025 Sep 5];40(6):505–15. Available from: https://pubmed.ncbi.nlm.nih.gov/22899561/
22. WHO. International Statistical Classification of Diseases and Related Health Problems 10th Revision. 2019; Available from: https://icd.who.int/browse10/2019/en
23. EU. GDPR [Internet]. 2025 [cited 2023 Dec 20]. Available from: https://europa.eu/youreurope/business/dealing-with-customers/data-protection/data-protection-gdpr/index_fi.htm
24. Beswick AD, Rees K, Dieppe P, Ayis S, Gooberman-Hill R, Horwood J, et al. Complex interventions to improve physical function and maintain independent living in elderly people: a systematic review and meta-analysis. Lancet. 2008;371(9614):725–35.
25. Tricco AC, Thomas SM, Veroniki AA, Hamid JS, Cogo E, Strifler L, et al. Comparisons of Interventions for Preventing Falls in Older Adults: A Systematic Review and Meta-analysis. JAMA [Internet]. 2017 Nov 7 [cited 2026 Apr 17];318(17):1687–99. Available from: https://pubmed.ncbi.nlm.nih.gov/29114830/
26. Kasicki K, Piskorz EK, Rydzik Ł, Ambroży T, Ceranowicz P, Błach W. A systematic review of multicomponent vs. single-component training programs for fall prevention in older adults. Front public Heal [Internet]. 2025 [cited 2026 Mar 30];13. Available from: https://pubmed.ncbi.nlm.nih.gov/40791619/
27. Adjetey C, Karnon B, Falck RS, Balasubramaniam H, Buschert K, Davis JC. Cost-effectiveness of exercise versus multimodal interventions that include exercise to prevent falls among community-dwelling older adults: A systematic review and meta-analysis. Maturitas [Internet]. 2023 Mar 1 [cited 2026 Mar 9];169:16–31. Available from: https://pubmed.ncbi.nlm.nih.gov/36630860/

Figures

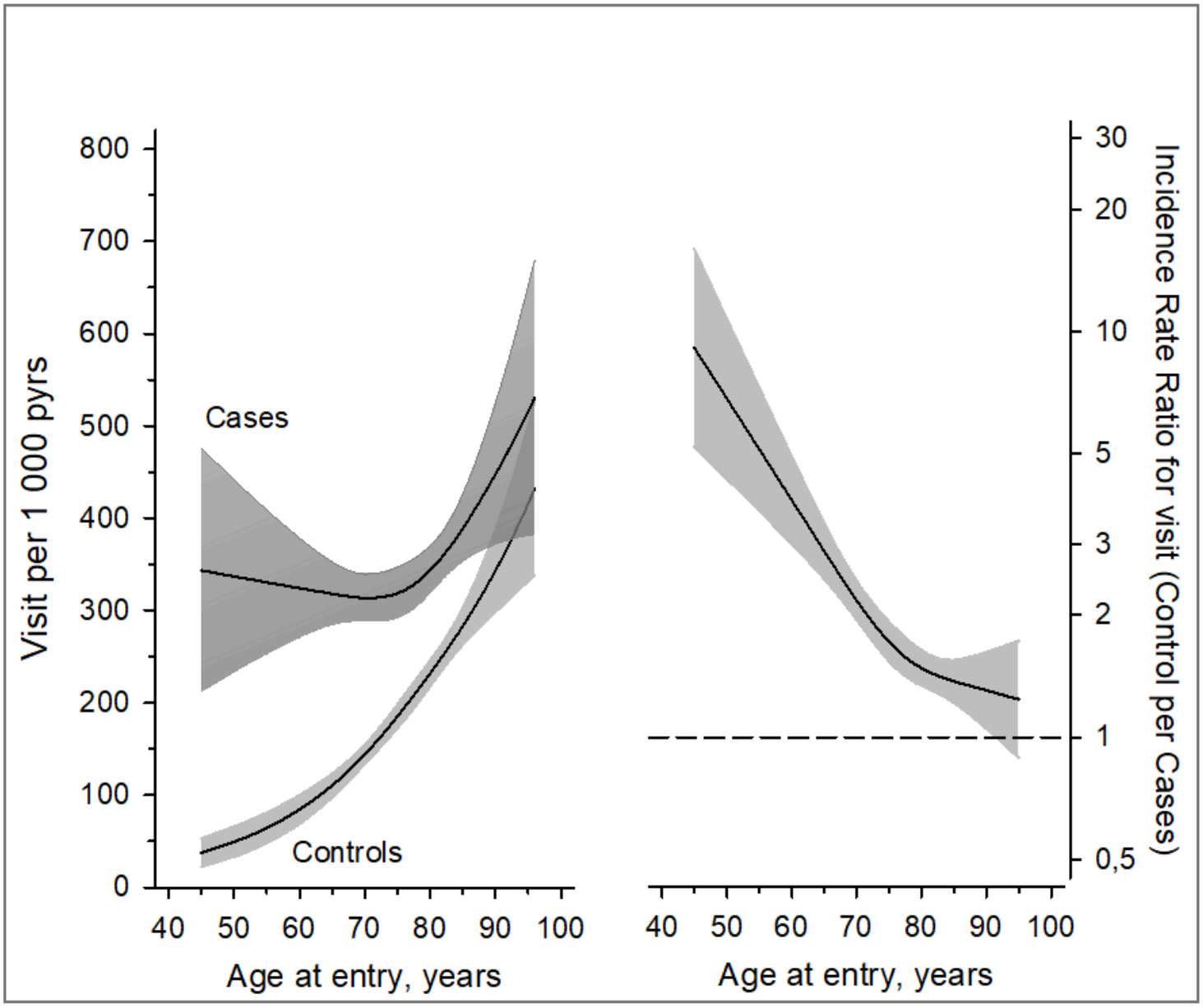


Figure 1

Injury-related outpatient visits among multifactorial falls prevention programme patients compared with age-, sex-, and residence-matched population-based controls. The curve was derived from a 3-knot restricted cubic spline Poisson regression model. Shaded area represents 95% confidence interval. Pyrs denotes follow-up person-years.

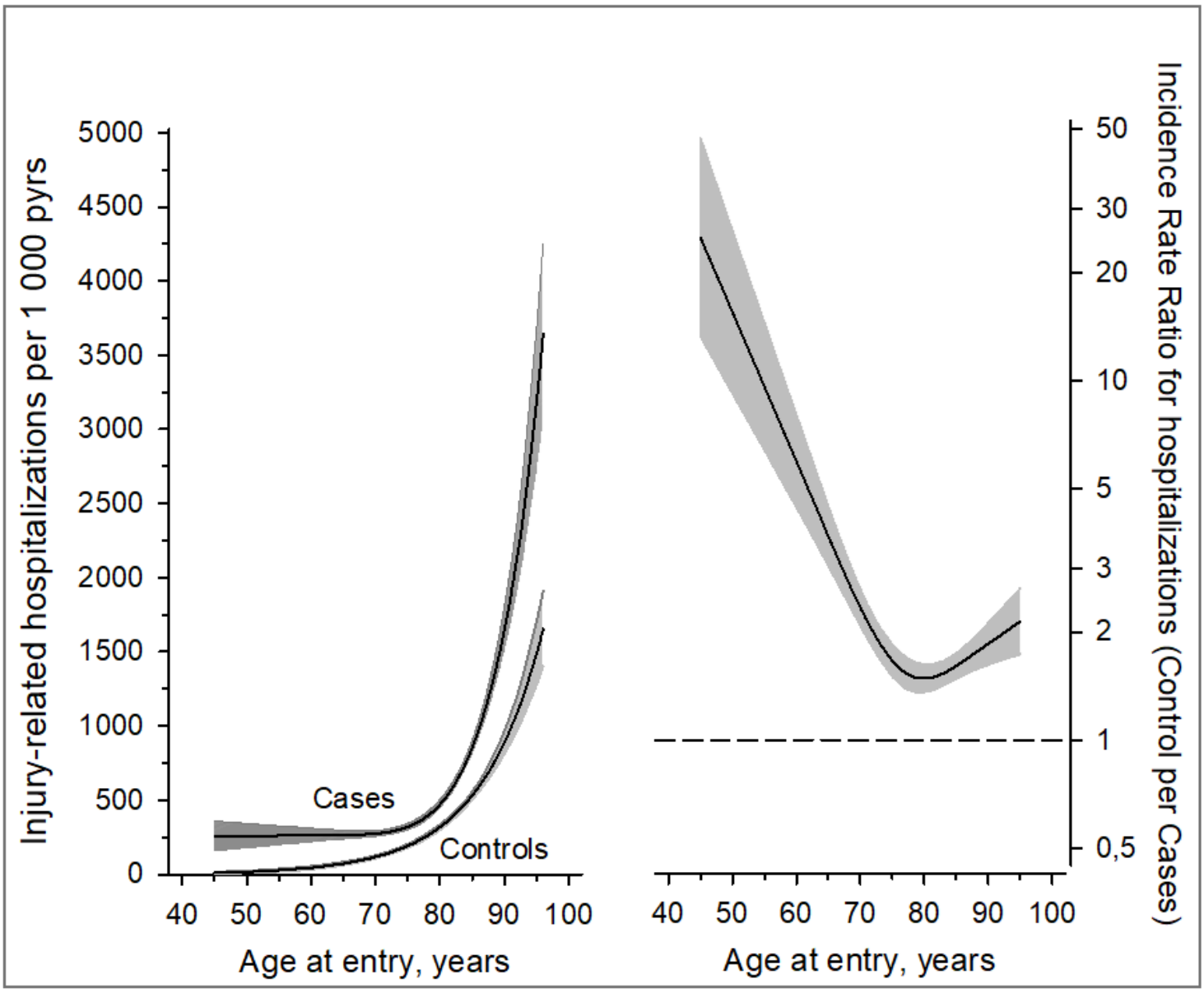


Figure 2

Injury-related hospitalizations among multifactorial falls prevention programme patients compared with age-, sex-, and residence-matched population-based controls. The curve was derived from a 3-knot restricted cubic spline Poisson regression model. Shaded area represents 95% confidence interval. Pyrs denotes follow-up person-years.

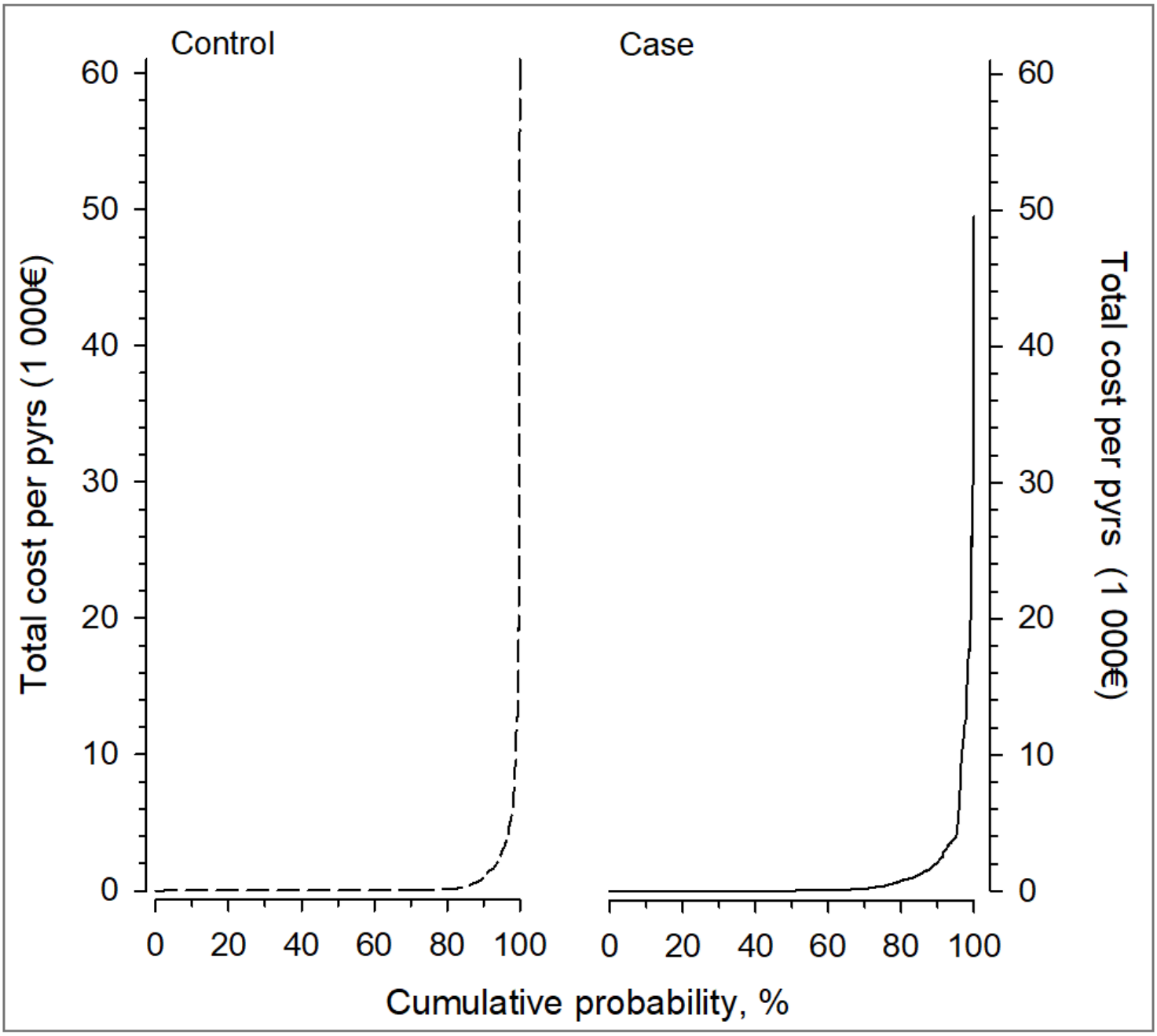


Figure 3

Injury-related costs among multifactorial falls prevention programme patients compared with age-, sex-, and residence-matched population-based controls.