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**RESEARCH PAPER**

# Fall-related health service use in *Stepping On* programme participants and matched controls: a non-randomised observational trial within the *45 and Up Study*

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## Abstract

**Background:** Falls and fall-related health service use among older adults continue to increase. The New South Wales Health Department, Australia, is delivering the *Stepping On* fall prevention programme at scale. We compared fall-related health service use in *Stepping On* participants and matched controls.
**Methods:** A non-randomised observational trial was undertaken using *45 and Up Study* data. *45 and Up Study* participants who did and did not participate in *Stepping On* were extracted in a 1:4 ratio. Rates of fall-related health service use from linked routinely collected data were compared between participants and controls over time using multilevel Poisson regression models with adjustment for the minimally sufficient set of confounders identified from a directed acyclic graph.
**Results:** Data from 1,452 *Stepping On* participants and 5,799 controls were analysed. Health service use increased over time and was greater in *Stepping On* participants (rate ratios (RRs) 1.47–1.82) with a spike in use in the 6 months prior to programme participation. Significant interactions indicated differential patterns of health service use in participants and controls: stratified analyses revealed less fall-related health service use in participants post-programme compared to pre-programme (RRs 0.32–0.48), but no change in controls' health service use (RRs 1.00–1.25). Gender was identified to be a significant effect modifier for health service use ($P < 0.05$ for interaction).
**Discussion:** *Stepping On* appeared to mitigate participants' rising fall-related health service use. Best practice methods were used to maximise this study's validity, but cautious interpretation of results is required given its non-randomised nature.

**Keywords:** accidental falls, health service utilisation, older adults, fall prevention, older people

### Key Points

- Fall-related health service use among older adults increased over time.

- A spike in health service use immediately before the programme likely indicated a crisis point prompting participants to seek help managing their falls.
- Participation in the *Stepping On* fall prevention programme appeared to mitigate participants' fall-related health service use.
- Future research should investigate ways to maximise population-level fall prevention among different subgroups of older adults.

## Introduction

Falls among older adults can result in injuries, with a quarter of injurious falls resulting in healthcare service use [1, 2], some requiring ongoing healthcare resources up to a year [1]. Rates of fall-related health service use have continued to increase over the past two decades [3, 4]. There is systematic review evidence that exercise interventions can reduce rates of falls [5] and fall injuries [6] in older adults, but few programmes are delivered at scale in Australia. *Stepping On* is a multiple-component fall prevention programme underpinned by behaviour change and exercise, involving seven weekly group sessions on a variety of fall prevention topics. It is targeted at community-dwelling people aged ≥65 years with intact cognition and who walk unaided but who are at risk of falls (i.e. have previously fallen or express fear of falling), but who do not have a neurodegenerative disease (e.g. Parkinson's disease). *Stepping On* was found to reduce the rate of falls by 31% in a randomised trial in Australia [7] and was implemented and tested in the USA [8, 9].

The Health Department of New South Wales (NSW), Australia, trialled implementation of the *Stepping On* programme across multiple districts in 2009 with gradual rollout across the state from 2012. The rationale was that if fall prevention programmes are implemented which reduce the number of falls, including injurious falls, then health service use will also diminish [6].

Our previous studies found lasting self-reported behaviour change in NSW-Health delivered *Stepping On* participants [10] but did not show a significant impact of the *Stepping On* state-wide rollout on fall-related hospitalisations or ambulance use at the NSW population level [11]. This finding was likely influenced by the small reach of the programme during the evaluation time period (<1% of the target population received the intervention). Our further study among programme participants indicated reduced fall-related health service use in the 12 months following programme participation, but found such benefits diminished over the subsequent 24 months [12]. This analysis suggested that fall-related health service use may have been a precursor to programme participation, but lack of a control group limited interpretation. The Sax Institute's *45 and Up Study* (a large population-based study with n = 267,357) [13] includes >1,000 *Stepping On* participants, providing a unique opportunity to compare programme participants with matched controls. We used linked data from the *45 and Up Study* to investigate whether fall-related health service use between *Stepping On* programme participants and matched community-dwelling controls differed prior to and following programme participation.

The primary research question was as follows:

(1) Is there a difference in fall-related health service use between *Stepping On* participants and matched controls, considering 1 year prior to and 1 year following programme participation?

The secondary research questions were:

(2) Were observed differences between *Stepping On* participants and controls maintained in the 3 years after programme participation?
(3) Was there evidence of a differential effect on fall-related health service use between *Stepping On* participants and controls based on gender, in the year following programme participation?

## Methods

### Protocol of the non-randomised observational trial

This study was conceptualised following the principles of a hypothetical randomised trial (Supplementary File S1), to increase the robustness of drawing causal inferences from an observational study [14]. Since participation in *Stepping On* was not randomly assigned to individuals in the dataset, we term our study an observational non-randomised trial.

### Datasets

We used linked data from the Sax Institute's *45 and Up Study*, a population-based cohort of older Australians living in NSW followed-up longitudinally in 5-year waves [13], and routinely collected health information. The Centre for Health Record Linkage (CHeReL) [15] used probabilistic linkage to link the *45 and Up Study* to the Admitted Patients Data Collection (APDC), Emergency Department Data Collection (EDDC), NSW Ambulance's computer aided dispatch (CAD), patient healthcare record (PHCR), electronic medical record (eMR) data collections, NSW Registry of Birth, Deaths and Marriages (RBDM) and Australian Bureau of Statistics (ABS) mortality data, and *Stepping On* participants from 1 July 2005 to 31 March 2016. This data linkage study was approved by the NSW Population and Health Services Research Ethics Committee (HREC/14/CIPHS/67) and is reported according to the REporting of studies Conducted using Observational Routinely-collected Data (RECORD) guidelines [16].

Details of the linkage conducted by the CHeReL and the resultant *45 and Up Study* sample are in Supplementary File S2. Of the 34,437 individuals from the *45 and Up Study* included in the linkage (i.e. age ≥65 years between 1 July 2009 and 31 March 2014), 1,672 (5%) participated in *Stepping On* and were categorised as the intervention group. As the *Stepping On* dataset (n = 9,903) did not include any health data on the participants, to minimise selection bias of controls [17], we included only *Stepping On* participants and controls from the *45 and Up Study* participants.

To maximise statistical power, we selected four controls per *Stepping On* participant [18]. We matched controls to *Stepping On* participants by gender, age, ability to walk, area-level socioeconomic position and fall history in two steps, as detailed in Supplementary File S3. Figure S3A in Supplementary File S3 outlines how participants and controls were selected for analysis.

### Outcomes

Fall-related health service use was calculated as the number of fall-injury hospital admissions, emergency department (ED) visits and emergency ambulance paramedic attendance. Hospital admissions were determined from the APDC as all episodes of care that constituted the overall hospital stay for each person. Fall-related injury admissions were determined from the APDC diagnoses codes. Falls which occurred in hospital, and non-acute recurrent admissions unlikely to be influenced by the *Stepping On* programme, were excluded. Hospital admissions were included if the overall length of stay was at least 24 h; day stays were excluded. Fall-related ED presentations were determined from the EDDC's presenting problem free-text field or the diagnosis code; planned visits and internal transfers were excluded to avoid overestimating the number of ED presentations. Fall-related ambulance use involving paramedics was determined from the protocols in the clinical records (i.e. PHCR or eMR) associated with valid transport dispositions. Deaths were censored using the RBDM and ABS mortality data; any deaths coded in the APDC, EDDC or Ambulance datasets were also censored. Supplementary File S3 outlines in detail how outcomes were derived from each dataset.

### Covariates

Potential confounders were identified using the authors' multidisciplinary expert knowledge and the literature (e.g. fall history, fear of falling, poor balance, poor mobility), and incorporated into a directed acyclic graph (DAG) using DAGitty v3.0 [19] to determine the minimally sufficient adjustment set (Figure S1 in Supplementary File S1). These covariates included 1-year recurrent fall history, pre-programme fall-related health service use, depression, mobility limitations (i.e. difficulty walking 500 m), poor health and remoteness (i.e. metropolitan, inner regional and outer regional/remote).

### Statistical analyses

Descriptive sociodemographic data were obtained from the *45 and Up Study* questionnaire which preceded *Stepping On* participation. Data from the baseline (2006–2009); Social, Economic and Environmental factors study (2010); or first wave follow-up (2012–2015) questionnaires were used. Missing data were reported as such. The time between completing the *45 and Up Study* questionnaire and *Stepping On* programme participation was similar between groups ($P = 0.33$; participants: mean 1238.5 days, SD 661.8, range 0–3,182; controls: mean 1220.2 days, SD 644.2, range 0–3,284).

Outcomes (i.e. the number of fall-injury hospital admissions, fall-related ED visits and emergency fall-related ambulance use involving paramedics) were calculated for 3-monthly intervals prior to and following *Stepping On* participation. Outcomes were standardised per 100-person-years for each group and presented descriptively.

Rates of fall-related health service use were compared between *Stepping On* participants and controls using multilevel Poisson regression models to estimate the rate ratios (RR) and 95% confidence intervals (CIs); as each individual contributed one observation per term and hence multiple observations over the study period, they were included as a repeated term in the models. Models were built iteratively to firstly examine the effect of treatment group (*Stepping On* participants vs control); then the effects of treatment group and programme period (i.e. pre/post); and finally, the effects of treatment group, programme period and the interaction of treatment group∗programme period. Follow-up duration was included as an exposure term in all models. To compare the rate of fall-related health service use between the two groups, follow-up duration was calculated as 1-year post-programme participation or the number of days until death. To examine whether there were long-term effects from the *Stepping On* programme, follow-up duration was extended to 3 years. All models included the covariates identified from the minimally sufficient adjustment set. If the interaction of treatment group∗programme period from the final model set was significant ($P < 0.20$), we performed stratified analyses to examine the effects by treatment group and programme period; similarly, if the interaction of group∗programme period∗gender was significant, we performed stratified analysis by gender. Sensitivity analyses were conducted examining a period of 3-year pre-programme participation, to examine whether earlier pre-programme health service use influenced the results. All analyses were conducted using SAS Enterprise Guide v7.1 (SAS Institute, Cary, NC, USA) in the Secure Unified Research Environment.

## Results

A total of 7,251 individuals were included in this observational non-randomised trial: 1,452 *Stepping On* participants and 5,799 controls, with <1% (n = 7) of participants having fewer than four matched controls. Table 1 reports characteristics of programme participants and controls. Overall,

**Table 1.** Characteristics of *Stepping On* participants and controls, *45 and Up Study*

| Characteristic[a] | *Stepping On* participants (*n* = 1,452) | Community-dwelling controls (*n* = 5,799) | Between-group difference *P*-value |
|---|---|---|---|
| Gender | | | 0.95 |
| Women | 1,083 (75%) | 4,331 (75%) | |
| Men | 369 (25%) | 1,468 (25%) | |
| Age (years) | 78.2 (7.4), 53–98 | 78.1 (7.2), 59–102 | 0.96 |
| <75[b] | 459 (32%) | 1,844 (32%) | 0.64 |
| 75–84 | 659 (45%) | 2,668 (46%) | |
| 85+ | 334 (23%) | 1,287 (22%) | |
| Remoteness area[c] | | | 0.002* |
| Major cities | 609 (42%) | 2,828 (49%) | |
| Inner regional | 695 (48%) | 2,351 (41%) | |
| Outer regional/remote | 148 (10%) | 620 (11%) | |
| IRSAD quintiles[d] | | | 0.99 |
| 1–2 | 326 (22%) | 1,302 (22%) | |
| 3–4 | 379 (26%) | 1,511 (26%) | |
| 5–6 | 315 (22%) | 1,260 (22%) | |
| 7–8 | 179 (12%) | 716 (12%) | |
| 9–10 | 253 (17%) | 1,010 (17%) | |
| Fell in past 12 months[e] | | | 0.43 |
| 0 | 947 (68%) | 3,779 (67%) | |
| 1 | 209 (15%) | 891 (16%) | |
| 2–9 | 219 (16%) | 926 (16%) | |
| 10+ | 12 (1%) | 47 (1%) | |
| Recurrent (2+) faller in past 12 months[e] | 231 (17%) | 973 (17%) | 0.63 |
| Housing[f] | | | 0.03* |
| Community | 1,227 (90%) | 5,201 (91%) | |
| Retirement village | 149 (10%) | 490 (9%) | |
| Self-rated health | | | |
| Poor health[g] | 20 (1%) | 142 (3%) | 0.01* |
| Poor QoL[h] | 13 (1%) | 91 (2%) | 0.06 |
| Requires assistance with ADLs[i] | 127 (9%) | 529 (10%) | 0.72 |
| Limitations performing ADLs | | | |
| Walking 100 m[j] | 229 (19%) | 926 (19%) | 0.80 |
| Walking half a kilometre[k] | 372 (31%) | 1,455 (30%) | 0.23 |
| Walking 1 km[l] | 542 (43%) | 2,111 (41%) | 0.27 |
| Climbing one flight of stairs[m] | 421 (34%) | 1,566 (31%) | 0.04* |
| Climbing several flights of stairs[n] | 821 (64%) | 3,037 (58%) | <0.001* |
| Bathing or dressing[o] | 131 (11%) | 586 (12%) | 0.34 |
| Lifting or carrying shopping[p] | 604 (48%) | 2,194 (42%) | <0.001* |
| Bending, kneeling, stooping[q] | 794 (61%) | 2,969 (56%) | 0.001* |
| Moderate activities[r] | 650 (51%) | 2,296 (45%) | <0.001* |
| Vigorous activities[s] | 1,188 (90%) | 4,600 (87%) | 0.002* |
| Physical activity (h) | | | |
| Sleeping in past 24 h[t] | 7.8 (1.6), 0–18 | 7.8 (1.6), 0–20 | 0.73 |
| Sitting in past 24 h[u,v] | 4.5 (3–6), 0–30 | 4.23 (3–6), 0–20 | 0.76 |
| Standing in past 24 h[u,w] | 3 (2–6), 0–18 | 3 (2–6), 0–20 | 0.42 |
| Walking ≥10 min in past week[u,x] | 2 (0.58–4), 0–98 | 2 (0.5–4), 0–82 | 0.80 |
| Time spent in MVPA in past week[u,y] | 0.4 (0.07–2), 0–100 | 0.38 (0.07–3), 0–105 | 0.30 |
| Fractures[z,aa] | | | |
| Hip | 10 (1%) | 76 (1%) | 0.06 |
| Wrist | 58 (4%) | 223 (4%) | 0.82 |
| Other bones | 158 (12%) | 710 (13%) | 0.15 |
| Comorbidities | | | |
| Anxiety[ab] | 172 (12%) | 509 (9%) | <0.001* |
| Depression[ab] | 208 (14%) | 710 (12%) | 0.03* |
| Asthma and/or hayfever[ac] | 326 (22%) | 1,288 (22%) | 0.86 |
| Thrombus[ac] | 134 (9%) | 464 (8%) | 0.14 |
| Cardiovascular disease | | | |
| Hypertension[ad] | 770 (53%) | 2,986 (51%) | 0.29 |
| Heart disease | 328 (23%) | 1,175 (20%) | 0.06 |

(*Continued*)

**Table 1.** Continued

| Characteristic[a] | *Stepping On* participants (*n* = 1,452) | Community-dwelling controls (*n* = 5,799) | Between-group difference *P*-value |
|---|---|---|---|
| Diabetes[ac] | 199 (14%) | 733 (13%) | 0.29 |
| Cancer | | | |
| Breast cancer[ae] | 88 (6%) | 348 (6%) | 0.90 |
| Prostate cancer[af] | 58 (4%) | 179 (3%) | 0.04* |
| Melanoma[ac] | 124 (9%) | 417 (7%) | 0.08 |
| Other skin cancer[ac,ag] | 518 (36%) | 1996 (34%) | 0.37 |
| Other cancers[ac] | 119 (8%) | 548 (9%) | 0.14 |
| Enlarged prostate[ah] | 129 (9%) | 494 (9%) | 0.33 |
| Stroke[ac] | 105 (7%) | 332 (6%) | 0.04* |
| Nil comorbidity[ac] | 133 (9%) | 610 (11%) | 0.13 |

Data were extracted from the *45 and Up Study* questionnaire closest to but prior to programme participation and are reported as n (%); mean (SD), range; or median (IQR), range. ADL, activity of daily living; IRSAD, index of relative socioeconomic advantage and disadvantage; MVPA, moderate-vigorous physical activity; QoL, quality of life. *Indicates statistical significance at $P < 0.05$. [a]Derivation of each characteristic from the *45 and Up Study* questionnaires is detailed in Table S3C of Supplementary File S3. [b]Very few were aged <65 years (*n* = 48 (3%) *Stepping On* participants and *n* = 156 (3%) controls). Thus, people aged <65 years and 65–74 years were collapsed into a single category. [c]The >5% between-group difference in metropolitan and inner regional areas is likely due to oversampling of people from regional and rural areas in the *45 and Up Study*, without difference (<1%) in outer regional/remote areas. The availability of the health services reported in this study is similar between metropolitan and inner regional areas, and less in outer regional/remote areas. [d]Lower scores indicate lower socioeconomic position. [e]Missing or unknown in *n* = 65 (4%) *Stepping On* participants and *n* = 156 (3%) controls. [f]Missing or unknown in *n* = 26 (2%) *Stepping On* participants and *n* = 108 (2%) controls. [g]Missing or unknown in *n* = 60 (4%) *Stepping On* participants and *n* = 210 (4%) controls. [h]Missing or unknown in *n* = 118 (8%) *Stepping On* participants and *n* = 386 (7%) controls. [i]Missing or unknown in *n* = 69 (5%) *Stepping On* participants and *n* = 258 (4%) controls. [j]Missing or unknown in *n* = 273 (19%) *Stepping On* participants and *n* = 957 (17%) controls. [k]Missing or unknown in *n* = 266 (18%) *Stepping On* participants and *n* = 877 (15%) controls. [l]Missing or unknown in *n* = 185 (13%) *Stepping On* participants and *n* = 652 (11%) controls. [m]Missing or unknown in *n* = 230 (16%) *Stepping On* participants and *n* = 817 (14%) controls. [n]Missing or unknown in *n* = 167 (12%) *Stepping On* participants and *n* = 545 (9%) controls. [o]Missing or unknown in *n* = 217 (15%) *Stepping On* participants and *n* = 743 (13%) controls. [p]Missing or unknown in *n* = 186 (13%) *Stepping On* participants and *n* = 635 (11%) controls. [q]Missing or unknown in *n* = 160 (11%) *Stepping On* participants and *n* = 543 (9%) controls. [r]Missing or unknown in *n* = 181 (12%) *Stepping On* participants and *n* = 669 (12%) controls. [s]Missing or unknown in *n* = 135 (9%) *Stepping On* participants and *n* = 516 (9%) controls. [t]Missing or unknown in *n* = 64 (4%) *Stepping On* participants and *n* = 245 (4%) controls. [u]Median (IQR) reported due to skewed data. [v]Missing or unknown in *n* = 170 (12%) *Stepping On* participants and *n* = 643 (11%) controls. [w]Missing or unknown in *n* = 303 (21%) *Stepping On* participants and *n* = 1,078 (19%) controls. [x]Missing or unknown in *n* = 179 (12%) *Stepping On* participants and *n* = 771 (13%) controls. [y]Missing or unknown in *n* = 189 (13%) *Stepping On* participants and *n* = 724 (12%) controls. [z]Other bones include ankle, arm, finger, rib or unknown. Fracture categories are not mutually exclusive, hence people may sustain multiple types of fractures. [aa]Missing or unknown in *n* = 129 (9%) *Stepping On* participants and *n* = 534 (9%) controls. [ab]Missing or unknown in *n* = 101 (7%) *Stepping On* participants and *n* = 352 (6%) controls. [ac]Missing or unknown in *n* = 0 (0%) *Stepping On* participants and *n* = 1 (0%) controls. [ad]Missing or unknown in *n* = 16 (1%) *Stepping On* participants and *n* = 60 (1%) controls. [ae]Missing or unknown in *n* = 280 (19%) *Stepping On* participants and *n* = 1,107 (19%) controls. [af]Missing or unknown in *n* = 862 (59%) *Stepping On* participants and *n* = 3,331 (57%) controls. [ag]Non-melanoma skin cancer. [ah]Missing or unknown in *n* = 863 (59%) *Stepping On* participants and *n* = 3,341 (58%) controls.

participants and controls were well matched across several sociodemographic factors. More controls lived in metropolitan areas and fewer in inner regional areas (>5% difference). *Stepping On* participants were more likely to report activity limitations than controls (3–6%). Participants and controls were majority women (75%) and on average aged 78 years (SD 7); this age and gender distribution is similar to that of the original *Stepping On* randomised trial [7]. A small proportion of the sample died during the follow-up period (participants: n = 86 (6%), mean 620.8 days, SD 277.7, range 55–1,073; controls: n = 477 (8%), mean 527.5 days, SD 269.4, range 50–1,093).

In both groups, health service use increased over time (Figure 1, Table 2). Fall-related health service use increased in the 3–6 months prior to programme participation among *Stepping On* participants but did not spike in the matched time periods among controls (Figure 1).

Comparison of between-group service use in the year prior to and year after programme participation indicated significant differences (RR 1.82, 95% CI 1.47–2.25 for fall-injury hospitalisations; 1.47, 95% CI 1.20–1.82 for fall-related ED visits; and 1.52, 95% CI 1.20–1.93 for Ambulance use) whereby *Stepping On* participants had higher rates of fall-related health service use than controls (Table 3). There was no difference in fall-related health service use when pre-programme and post-programme periods were compared (Table 3). However, treatment group and programme period interactions were significant, indicating use patterns pre- and post-programme differed by group. Stratified analysis by group showed that participants' fall-related health service use reduced post-programme compared to pre-programme, but there were no pre-post programme period differences in controls' health service use (Table 4). Stratified analyses by programme period showed that *Stepping On* participants' fall-related health service use was greater than controls prior to the programme, but not significantly different than controls post-programme, except for fall-injury hospitalisations in the 1-year post-programme (Table 4).

Analysis of the 3-year post-programme participation revealed a similar pattern of outcomes. However, the rates of fall-injury hospitalisations among the *Stepping On* participants were no longer significant at 3-year post-programme nor compared to controls (Table 4). Additionally, ambulance use increased among controls at 3-year post-programme. Sensitivity analyses extending the pre-programme analysis period to 3 years revealed a similar pattern of results, with

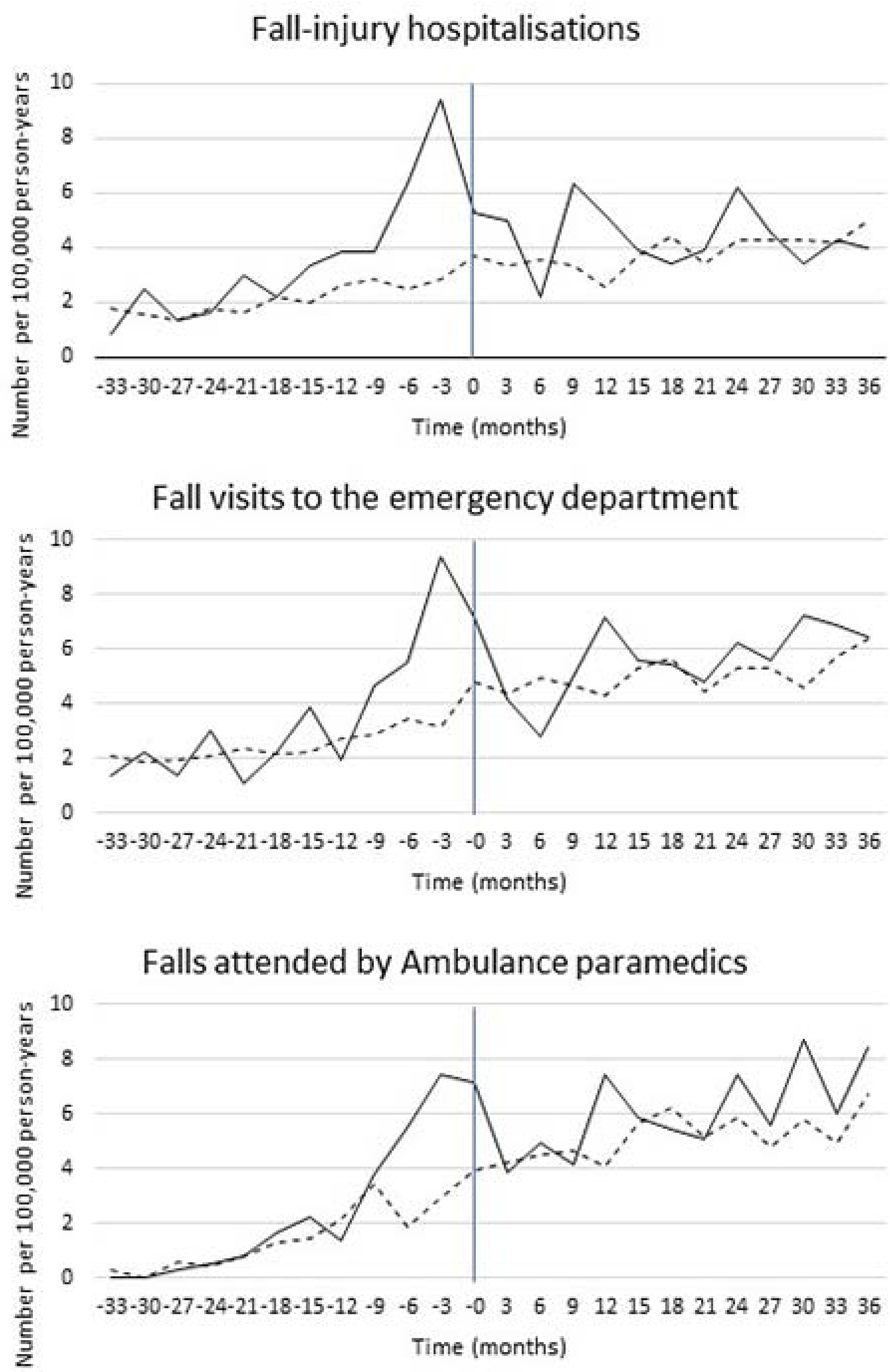


**Figure 1.** Fall-related health service use over time by intervention group. Timepoints on the horizontal axis are cumulative 3-month periods to the respective number (e.g. −33 refers to the period 33–36 months prior to programme start). Zero (0) indicates start of the *Stepping On* programme, negative numbers time prior to and positive numbers time following programme participation. Solid lines indicate *Stepping On* participants, dashed lines control participants.

the apparent mitigating effects of the programme on fall-related health service use generally less evident at 3-year follow-up (Supplementary File S4).

Subgroup analyses showed a significant impact of gender (interaction term $P < 0.05$) on pattern of fall-related health service use between groups (Supplementary File S5, Figure S5A and Table S5B). A similar pattern to the main effects of treatment group, programme period and treatment group∗programme period interaction for the entire cohort was present in women. However, in men there was no observed difference by group, programme period or any group∗programme period interactions, which is mainly due to the smaller sample size of men in our study (Supplementary File S5, Table S5C).

**Table 2.** Counts of health service use by *Stepping On* participants and controls, prior to and following programme participation, with death censored

| Health service use | *Stepping On* (*n* = 1,452) | | | | Controls (*n* = 5,799) | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 years pre | 1 year pre | 1 year post | 3 years post | 3 years pre | 1 year pre | 1 year post | 3 years post |
| ***Fall-injury hospital admissions (>24 h stays)*** | | | | | | | | |
| 0 | 1,321 (91%) | 1,375 (95%) | 1,391 (96%) | 1,313 (90%) | 5,465 (94%) | 5,637 (97%) | 5,638 (97%) | 5,342 (92%) |
| 1 | 109 (8%) | 67 (5%) | 55 (4%) | 116 (8%) | 287 (5%) | 152 (3%) | 146 (3%) | 380 (7%) |
| 2–5 | 22 (2%) | 10 (1%) | 6 (0.4%) | 23 (2%) | 47 (1%) | 10 (0.2%) | 15 (0.3%) | 77 (1%) |
| 6–10 | ^ | ^ | ^ | ^ | ^ | ^ | ^ | ^ |
| 11–99 | ^ | ^ | ^ | ^ | ^ | ^ | ^ | ^ |
| ***Fall-related emergency department visits*** | | | | | | | | |
| 0 | 1,319 (91%) | 1,366 (94%) | 1,391 (96%) | 1,287 (89%) | 5,440 (94%) | 5,619 (97%) | 5,580 (96%) | 5,224 (90%) |
| 1 | 114 (8%) | 76 (5%) | 54 (4%) | 130 (9%) | 293 (5%) | 162 (3%) | 196 (3%) | 467 (8%) |
| 2–5 | 19 (1%) | 10 (1%) | 7 (1%) | 35 (2%) | 66 (1%) | 18 (0.3%) | 21 (0.4%) | 103 (2%) |
| 6–10 | ^ | ^ | ^ | ^ | ^ | ^ | ^ | ^ |
| 11–99 | ^ | ^ | ^ | ^ | ^ | ^ | ^ | ^ |
| ***Falls attended by ambulance paramedics*** | | | | | | | | |
| 0 | 1,359 (94%) | 1,383 (95%) | 1,391 (96%) | 1,287 (89%) | 5,564 (96%) | 5,640 (97%) | 5,601 (97%) | 5,244 (90%) |
| 1 | 76 (5%) | 53 (4%) | 50 (3%) | 125 (9%) | 198 (3%) | 143 (2%) | 164 (3%) | 430 (7%) |
| 2–5 | 17 (1%) | 16 (1%) | 11 (1%) | 40 (3%) | 37 (1%) | 16 (0.3%) | 33 (1%) | 119 (2%) |
| 6–10 | ^ | ^ | ^ | ^ | ^ | ^ | ^ | 6 (0.1%) |
| 11–99 | ^ | ^ | ^ | ^ | ^ | ^ | ^ | ^ |

^A chevron (^) denotes $n < 5$. Note that suppressing cells with $n < 5$ is a requirement of the Sax Institute's *45 and Up Study* ethical requirements.

## Discussion

This observational non-randomised trial among a subset of older adults from the Sax Institute's *45 and Up Study* showed a differential pattern in fall-related health service use prior to and following the *Stepping On* programme between participants and matched controls. Fall-related health service use increased over time. Although participants had overall greater health service use than controls, the programme appeared to have mitigating effects among participants. Sensitivity analyses demonstrated the stability of these results. Subgroup analyses further revealed the impact of gender on the *Stepping On* programme.

*Stepping On* is known to reduce falls among older adults [7, 20]. However, reducing falls may not necessarily reduce fall-related health service use. Nevertheless, we found that the programme mitigated rising rates of fall-related ED visits in the year following programme participation, similar to findings from a previous study in the USA [8]. The programme appeared to mitigate rising rates of fall-injury hospitalisation over a longer term (3 years), which is encouraging in light of ongoing increases in such admissions among older Australians [21]. The pattern suggesting increased presentation to the ED and use of ambulance services over time may coincide with changing practices over the study period. For example, Ambulance NSW implemented paramedic-led falls screening strategies among older adults [22]. While only a small proportion of falls result in severe injury requiring health utilisation, they represent a substantial proportion of injury hospitalisations and costs (e.g. 77%) [23], and are rising, in particular for men.

The pre-programme increase in fall-related health service use was similar to the pattern among a larger cohort of *Stepping On* participants [12] and may indicate a crisis point which prompts older adults to seek help managing their falls. As mobility limitations, poor health, depression and anxiety are associated with fear of falling [24], the larger proportion of participants reporting these problems may partially explain this observation. However, we were unable to ascertain reasons for programme referral nor sources of such referral from our datasets. Future research could explore the complex relationship between falls risk and health service utilisation. Use of fall-related health services by older adults should prompt healthcare providers to refer these individuals to appropriate fall management programmes.

We found effect modification by gender. Women appeared to obtain benefits in reducing fall-related health service use following programme participation. However, participants who were men were similar in their pattern of fall-related health service use as controls who were men over the entire study period. It also appeared that men used more fall-related health services than women (Supplementary Figure S5A). Others have demonstrated how women are more likely than men to seek medical care for falls when needed and/or talk to a healthcare provider about falls [25]. It may be that men are at higher risk at the time of seeking services [26] and may require earlier or more tailored programmes. Insights into the experience of men in fall prevention suggest health professionals may need to better engage with men at different stages in their awareness of fall risk and preferences for action [27, 28]. Under research conditions, there has been an apparent increased effect on fall reduction in men from this and other group-based fall-prevention programmes [7, 29].

Multiple-component programmes have been shown to reduce the rate of falls in meta-analysis [30].

**Table 3.** Rates of health service use between *Stepping On* participants and controls prior to and following programme participation ($n$ = 7,251)

| Outcome | Modelling the effect of: group | | Modelling the effects of: group + programme period | | Modelling the effects of: group + programme period + group*programme period | |
|---|---|---|---|---|---|---|
| | RR (95% CI) | *P* | RR (95% CI) | *P* | RR (95% CI) | *P* |
| **Research question 1**[a] | | | | | | |
| *Fall-injury hospitalisations* | | | | | | |
| Group (participants) | 1.82 (1.47–2.25) | <0.001* | 1.82 (1.47–2.25) | <0.001* | 1.80 (1.45–2.23) | <0.001* |
| Programme pre/post (post) | – | | 0.82 (0.56–1.19) | 0.30 | 0.77 (0.52–1.12) | 0.17 |
| Group * programme pre/post (participants at post) | – | | – | | 0.70 (0.47–1.06) | 0.09 |
| *Fall-related ED visits* | | | | | | |
| Group (participants) | 1.47 (1.20–1.82) | <0.001* | 1.47 (1.20–1.82) | <0.001* | 1.46 (1.18–1.81) | 0.001* |
| Programme pre/post (post) | – | | 0.74 (0.53–1.04) | 0.08 | 0.64 (0.46–0.90) | 0.01* |
| Group * programme pre/post (participants at post) | – | | – | | 0.56 (0.38–0.81) | 0.002* |
| *Falls attended by paramedics* | | | | | | |
| Group (participants) | 1.52 (1.20–1.93) | 0.002* | 1.52 (1.20–1.93) | 0.002* | 1.54 (1.21–1.95) | 0.002* |
| Programme pre/post (post) | – | | 0.91 (0.64–1.28) | 0.59 | 0.81 (0.57–1.14) | 0.23 |
| Group * programme pre/post (participants at post) | – | | – | | 0.59 (0.41–0.86) | 0.007* |
| **Research question 2**[b] | | | | | | |
| *Fall-injury hospitalisations* | | | | | | |
| Group (participants) | 1.42 (1.20–1.68) | <0.001* | 1.42 (1.20–1.68) | <0.001* | 1.61 (1.35–1.92) | <0.001* |
| Programme pre/post (post) | – | | 0.86 (0.68–1.09) | 0.21 | 0.76 (0.59–0.97) | 0.03* |
| Group * programme pre/post (participants at post) | – | | – | | 0.56 (0.40–0.78) | 0.001* |
| *Fall-related ED visits* | | | | | | |
| Group (participants) | 1.31 (1.12–1.53) | 0.002* | 1.31 (1.12–1.53) | 0.002* | 1.49 (1.26–1.76) | <0.001* |
| Programme pre/post (post) | – | | 0.96 (0.77–1.19) | 0.70 | 0.84 (0.68–1.05) | 0.13 |
| Group * programme pre/post (participants at post) | – | | – | | 0.58 (0.43–0.79) | 0.001* |
| *Falls attended by paramedics* | | | | | | |
| Group (participants) | 1.31 (1.11–1.56) | 0.004* | 1.31 (1.11–1.56) | 0.004* | 1.52 (1.26–1.84) | <0.001* |
| Programme pre/post (post) | – | | 1.10 (0.89–1.35) | 0.40 | 0.97 (0.78–1.21) | 0.78 |
| Group * programme pre/post (participants at post) | – | | – | | 0.58 (0.42–0.80) | 0.003* |

ED, emergency department; RR, rate ratios; 95% CI, 95% confidence interval. Results are reported from adjusted multilevel models. Higher RRs indicate greater rates of fall-related health service use. *Indicates a statistically significant effect at $P < 0.05$. [a]Research question 1 analysed the period 12 months prior through to 12 months following programme participation. [b]Research question 2 analysed the period 12 months prior through to 36 months following programme participation.

Multiple-component programmes like *Stepping On* address multiple fall risk factors and suit community-dwelling older people at risk of falls. They can act as a leverage to pursue ongoing prevention activities, including community exercise and reviewing medications with their doctor or pharmacist. But such programmes should not be the only approach used for fall prevention among older adults. Different fall prevention strategies are needed dependent on circumstances, personal risk and stage in life [31]. Differences in metropolitan and rural areas need consideration such as in infrastructure, technology support and scalable clinical-community referral systems [32]. Nevertheless, the results of this study suggests that ongoing widespread implementation of *Stepping On*, an inexpensive and cost-effective intervention [33], may help mitigate rising fall-related healthcare expenditure [2].

Best practice methods were used to maximise this study's validity including the principles of a hypothetical trial to guide study design and a DAG to guide the choice of covariates included in models. Nonetheless, there remain limitations that should be considered when interpreting these results. As this was a cohort study that attempted to replicate a randomised trial, certain inclusion and exclusion criteria could not be applied with certainty among the control group. Poor data quality of the *Stepping On* cohort collected by NSW Health limited our ability to draw inferences, as key variables such as number of falls and participant fear of falling were not available for analysis. The poor data quality of the cohort with limited number of identifiers available for probabilistic linkage of *Stepping On* participants to the *45 and Up Study* and routinely collected health datasets also resulted in a greater number of false linkages than the usual rate of 0.5% [15]. This resulted in exclusion of a small number of *Stepping On* participants and controls (0.1%) due to the inability to reconcile records across datasets. Coding

**Table 4.** Stratified analyses (adjusted multilevel models) by the effect of group and by programme pre/post for research questions 1 and 2, following significant group∗programme pre/post interactions ($P < 0.20$) in the main models

| | Analysis stratified by treatment group | | | | Analysis stratified by programme period | | | |
|---|---|---|---|---|---|---|---|---|
| | Participants (at post) | | Controls (at post) | | Pre-programme (participants) | | Post-programme (participants) | |
| Outcome | RR (95% CI) | P | RR (95% CI) | P | RR (95% CI) | P | RR (95% CI) | P |
| ***Research question 1*** | | | | | | | | |
| Fall-injury hospitalisations | 0.48 (0.25–0.91) | 0.03* | 1.04 (0.66–1.64) | 0.88 | 2.15 (1.62–2.86) | <0.001* | 1.51 (1.11–2.05) | .02* |
| Fall-related ED visits | 0.32 (0.18–0.56) | <0.001* | 1.00 (0.67–1.49) | 0.99 | 2.00 (1.54–2.61) | <0.001* | 1.07 (0.80–1.45) | .65 |
| Falls attended by paramedic | 0.38 (0.21–0.70) | 0.002* | 1.25 (0.83–1.89) | 0.28 | 2.00 (1.49–2.68) | <0.001* | 1.18 (0.87–1.61) | 0.31 |
| ***Research question 2*** | | | | | | | | |
| Fall-injury hospitalisations | 0.70 (0.45–1.09) | 0.11 | 0.95 (0.72–1.26) | 0.72 | 2.15 (1.62–2.86) | <0.001* | 1.20 (0.98–1.46) | 0.09 |
| Fall-related ED visits | 0.55 (0.36–0.82) | 0.003* | 1.16 (0.90–1.48) | 0.26 | 2.00 (1.54–2.61) | <0.001* | 1.12 (0.94–1.35) | 0.21 |
| Falls attended by paramedic | 0.64 (0.42–0.97) | 0.03* | 1.33 (1.04–1.69) | 0.03* | 2.00 (1.49–2.68) | <0.001* | 1.16 (0.96–1.41) | 0.14 |

ED, emergency department; RR, rate ratios; 95% CI, 95% confidence interval. Results are reported from adjusted multilevel models. Higher RRs indicate greater rates of fall-related health service use. *Indicates a statistically significant effect at $P < 0.05$.

limitations within the routinely collected data [34], e.g. difficulty ascertaining falls, particularly in the ED, may have led to underestimation of falls, though this is likely to affect both groups similarly. To increase the ascertainment of falls in the EDDC, we utilised the free-text field in addition to the diagnosis code.

In conclusion, this non-randomised observational trial found that participation in fall prevention interventions such as *Stepping On* appears to reduce age-related increases in fall-related health service use, whereby participants' high rates of pre-programme fall-related health service use reduced to a similar level as controls following programme participation. Future research should investigate ways to maximise population-level fall prevention among different subgroups of older adults.

**Supplementary Data:** Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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