

RESEARCH PAPER

Eight-year longitudinal falls trajectories and associations with modifiable risk factors: evidence from The Irish Longitudinal Study on Ageing (TILDA)

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Abstract

Background: The label 'faller' and the associated stigma may reduce healthcare-seeking behaviours. However, falls are not inevitably progressive and many drivers are modifiable. This observational study described the 8-year longitudinal trajectories of self-reported falls in The Irish Longitudinal Study on Ageing (TILDA) and studied associations with factors, including mobility, cognition, orthostatic hypotension (OH), fear of falling (FOF) and use of antihypertensive and antidepressant medications.

Methods: Participants aged ≥ 50 years at each wave were categorised by whether they averaged ≥ 2 falls in the previous year (recurrent fallers) or not (≤ 1 fall). Next-wave transition probabilities were estimated with multi-state models.

Results: 8,157 (54.2% female) participants were included, of whom 586 reported ≥ 2 falls at Wave 1. Those reporting ≥ 2 falls in the past year had a 63% probability of moving to the more favourable state of ≤ 1 fall. Those reporting ≤ 1 fall had a 2% probability of transitioning to ≥ 2 falls. Besides older age and higher number of chronic conditions, factors that increased the risk of transitioning from ≤ 1 fall to ≥ 2 falls were lower Montreal Cognitive Assessment score, FOF and taking antidepressants. Conversely, male sex, higher timed up and go time, the presence of OH and being on antidepressants reduced the probability of improving from ≥ 2 falls to ≤ 1 fall.

Conclusion: The majority of recurrent fallers experienced favourable transitions. Improvements in cognitive and psychological status, psychotropic prescribing, mobility and OH may help improve trajectories. Findings may help combat stigma associated with falling and promote preventative healthcare-seeking behaviours.

Keywords: falls, longitudinal, transitions, cognition, mobility, orthostatic hypotension, antidepressant, older people

Key Points

- This study describes the longitudinal trajectories of self-reported falls and associations with potentially modifiable factors.
- Falling does not signal a progressive and inevitable deterioration.
- Improved mobility, psychotropic prescribing, and orthostatic hypotension may increase the risk of positive falling trajectories.
- Improved cognitive and psychological status, and psychotropic prescribing may reduce the risk of negative falling trajectories.

Background

There is much clinical, academic and societal attention directed at reducing falls [1, 2]. For older adults, a fall, whether or not it results in serious injury, may represent a life-changing event that carries implications for their perceived health and behaviour. Qualitative research reveals that much of the individual impact arises from being labelled a ‘faller’ due to the negative connotations and stigma it carries in relation to physical and mental competence, and the perception of frailty [3–5]. The stigma may be affected by sex and socioeconomic factors [6] and is thought to be a barrier to people reporting falls [7] and initiating healthcare-seeking behaviours [8]. This may result in older people not benefiting from evidence-based multifaceted interventions that will reduce the risk of future falls [2] and in turn making the negative self-perceptions of ageing become a ‘self-fulfilling prophecy’ [9].

Work has shown that the ‘frailty’ label, regardless of how it is measured, is dynamic and fluctuates over time, with future improvements in the condition being frequent [10–13]. Yet, whether this longitudinal dynamism applies to the ‘faller’ label has been less studied. Greater understanding of longitudinal falling trajectories in older people may help reduce the stigma of falling without reducing its clinical importance and promote healthcare-seeking behaviours. This observational study aimed to describe the longitudinal trajectories of self-reported falls and their associations with potentially modifiable risk factors using the 8-year data collected in Waves 1–5 of The Irish Longitudinal Study on Ageing (TILDA).

Methods

Setting

We analysed data from TILDA, a population-based longitudinal study of community-dwelling adults aged 50 years and over in Ireland. Wave 1 of the study took place between October 2009 and July 2011, and subsequent data were collected approximately 2-yearly over four additional waves. At each wave, participants completed a computer-assisted personal interview and a self-completion questionnaire. The full cohort profile has been described elsewhere [14]. In TILDA, the 50+ age cut-off had the overarching aim of maximising the potential of research findings to translate into evidence-based preventative interventions during midlife.

Participants

We included TILDA Wave 1 participants aged 50 years and over who had self-reported falls information at TILDA Wave 1 (2010).

Ethics

Ethical approval for each wave was obtained from the Faculty of Health Sciences Research Ethics Committee at Trinity College Dublin, Ireland. All participants provided written informed consent.

Measures

Sociodemographic variables

We collected information on age (years), sex (male, female), and educational attainment. Educational attainment was categorised as ≤ 8 years (primary), 9–13 years (secondary) or > 13 years (tertiary/higher) of education.

Co-morbidities

The number of self-reported doctor-diagnosed chronic conditions were counted from the following list: hypertension; high cholesterol; angina; heart attack; heart failure; diabetes; stroke; transient ischemic attack (TIA); heart murmur; heart rhythm problem; other cardiovascular disease; chronic lung disease; asthma; arthritis; osteoporosis; cancer or malignant tumour (excluding minor skin cancers); Parkinson’s disease; emotional/nervous/psychiatric condition (e.g. depression and/or anxiety); alcohol or substance abuse; Alzheimer’s disease, dementia or serious memory impairment; stomach ulcers; varicose ulcers; cirrhosis or serious liver damage; cataracts; glaucoma; and age-related macular degeneration.

Cognition

The Montreal Cognitive Assessment (MoCA) was used as a measure of global cognition [15]. The MoCA is widely used in clinical practice and scored out of 30 points.

Mobility

We used the Timed Up and Go (TUG) test [16] as a well-validated measure of functional mobility. Participants were asked to rise from the chair, walk 3 m at normal pace to a line clearly marked on the floor, turn around, walk back to the chair, and sit down again. Normal values have been previously published [17].

Orthostatic hypotension

Blood pressure (BP) was measured after at least thirty minutes of sitting, and a second reading was taken 1 minute after standing. Orthostatic hypotension (OH) was defined as a drop in systolic BP of ≥ 20 mmHg and/or diastolic BP of ≥ 10 mmHg between the sitting and standing values [18].

Fear of falling

Participants were asked if they were afraid of falling (yes/no); if yes, they were asked ‘do you feel somewhat afraid or very much afraid of falling?’. A single-question fear of falling (FOF) assessment has shown good agreement with the Falls Efficacy Scale-International [19].

Use of antihypertensive and antidepressant medications

We recorded whether participants were taking any of these prescribed drugs, as per Anatomical Therapeutic Chemical (ATC) Classification System codes (https://www.whocc.no/atc_ddd_index/) [20].

Further characterisation variables

For descriptive-only purpose, we collected body mass index (BMI) in kg/m², number of prescribed regular medications, and handgrip strength [17].

Falls

At their first assessment, participants reported whether they had fallen in the past year. In subsequent waves participants were asked whether they had fallen since their previous assessment. As waves were approximately two years apart, the number of falls since previous assessments were divided by two and rounded to the nearest integer. In line with the World Guidelines of Falls Prevention and Management's definition of 'high risk of falls' [2] we separated participants at each wave by whether or not they averaged two or more falls in the previous year ('one or no falls' versus 'two or more falls').

Mortality was ascertained for all study participants at each follow-up wave [21]. Other than deaths, attrition at each wave was classified as 'missing'. Data missing at subsequent waves was for a variety of reasons including loss to follow up, withdrawal, and moving outside of Ireland. A small number at each wave (maximum of 14 participants) answered that they did not know how many times they had fallen.

Analysis

Data were analysed with R software [22]. Descriptive statistics were presented as mean with standard deviation ($\pm$ SD), median with interquartile range (IQR), or count with percentage (%). Comparisons between the two falls groups were conducted with the *t*-test (normally distributed variables), Wilcoxon rank sum test (non-normally distributed variables), and Pearson's chi-square test (categorical variables).

For the alluvial chart of the longitudinal trajectories of falls categories, the R ggalluvial package was used [23]. To examine longitudinal transitions between the two falls categories ('one or no falls' versus 'two or more falls') we used multi-state Markov models using the R msm package [24]. The model is a way of describing a process in which individuals move through a series of states over time. All missing data were censored and initially considered missing at random. We conducted sensitivity analyses where missing data were modelled as an additional state in the models. We obtained matrices of estimated transition probabilities from Wave *x* to Wave *x* + 1 (with 95% confidence intervals [CIs]) for each falls state. We added the following co-variables to the model to examine their effect on the risk of transitioning between the falls categories: age (in 5-year intervals), age, sex, level of education (using 'primary' as a reference category), number of chronic conditions, TUG time, MOCA score, the presence of OH, FOF (using 'not afraid' as a reference category), and use of antidepressants and antihypertensives. The inclusion of TUG, MoCA and OH is due to previous work that described a 'Bermuda triangle' of falls risk in older

people, characterised by gait disorder, cognitive impairment, and postural hypotension [25, 26]. Other covariates were chosen based on previous research and an emphasis on including potentially modifiable factors [27–30]. All covariates were the values from Wave 1 assessment and remained constant across waves. Hazard ratios (HRs) and 95% CIs for the estimated covariate were obtained. HRs were considered significant when their CIs did not include 1.

Results

Wave 1 recruited a total of 8,504 participants, of whom 330 (3.9%) were aged less than 50 years. Of the remaining participants, 8,154 had complete falls data. Table 1 shows the difference between those reporting one or no falls and those reporting two or more falls in the previous year at Wave 1. Those reporting two or more falls were, on average, older, and had higher BMI, higher number of chronic conditions (including myocardial infarction, heart failure, stroke or TIA; but excluding cancer), higher number of medications (including antidepressants but excluding anti-hypertensives), and lower parameters of physical and cognitive functioning. A greater proportion of those reporting two or more falls in the previous year had left education after primary school, were more fearful of falling, and had OH (Table 1).

The alluvial plot for the falls states in the total sample is shown in Figure 1. By Wave 5, 1,058 participants had died, and there were 3,303 participants with missing falls data.

The probabilities of moving from one state to another are presented in Figure 2. Those reporting two or more falls in the past year had a 63% (95% CI: 59–66%) probability of moving to the favourable state of 'one or no falls', though an 11% (95% CI: 8–14%) probability of dying before the next wave. Those reporting one or no falls had a 2% (95% CI: 2–3%) probability of transitioning to the unfavourable state of 'two or more falls' and a 4% (95% CI: 3–4%) probability of death. The next-wave probability of remaining in the unfavourable state of 'two or more falls' was 26% (95% CI: 24–29%).

Hazard ratios for the effect of the covariates (age, sex, education, number of chronic conditions, TUG, MoCA, OH, FOF, and use of antihypertensives and antidepressants) on the transitions are presented in Table 2. In those reporting two or more falls in the previous year, the risk of moving to a favourable state of 'one or no falls' at the next wave was 28% higher for female participants, 11% lower for each extra second taken to complete the TUG, 28% lower for those with OH, and 35% lower for those taking antidepressants. In those reporting one or no falls in the previous year, the risk of moving to the unfavourable state of 'two or more falls' was higher by 12% for every 5 years of age, 28% higher for every additional chronic condition, 7% lower for every 1 additional MoCA point, 87% higher for those taking antidepressants, and 49% and 169% respectively for those reporting being somewhat afraid or very afraid of falling

Table 1. Sample characteristics at Wave 1

Variable	All	<2 falls	2+ falls	<i>P</i> value for difference
<i>n</i>	8,154	7,568	586	
Age	63.8 (±9.8)	63.7 (±9.7)	65.2 (±10.3)	<i>P</i> = 0.001
Female	4,421 (54.2%)	4,099 (54.1%)	322 (54.9%)	<i>P</i> = 0.736
BMI	28.7 (±5.1)	28.6 (±5.0)	29.3 (±5.4)	<i>P</i> = 0.009
Education: primary	2,500 (30.7%)	2,288 (30.2%)	212 (36.2%)	<i>P</i> = 0.003
Education: secondary	3,253 (39.9%)	3,031 (40.1%)	222 (37.9%)	<i>P</i> = 0.318
Education: tertiary/higher	2,397 (29.4%)	2,245 (29.7%)	152 (25.9%)	<i>P</i> = 0.062
Number of chronic conditions	1.0 (1.0–3.0)	1.0 (1.0–3.0)	2.0 (1.0–3.0)	<i>P</i> < 0.001
Myocardial infarction	378 (4.6%)	340 (4.49%)	38 (6.48%)	<i>P</i> = 0.035
Heart failure	87 (1.2%)	72 (0.95%)	15 (2.56%)	<i>P</i> < 0.001
Stroke or TIA	290 (3.6%)	248 (3.3%)	42 (7.2%)	<i>P</i> < 0.001
Cancer	512 (6.3%)	469 (6.2%)	43 (7.3%)	<i>P</i> = 0.313
Number of medications	2.0 (0.0–4.0)	2.0 (0.0–4.0)	3.0 (1.0–6.0)	<i>P</i> < 0.001
On antidepressant	550 (6.8%)	462 (6.1%)	88 (15.0%)	<i>P</i> < 0.001
On antihypertensive	3,077 (37.7%)	2,848 (37.6%)	230 (39.3%)	<i>P</i> = 0.459
Fear of falling: Not afraid	6,258 (76.7%)	5,939 (78.5%)	319 (54.4%)	<i>P</i> < 0.001
Fear of falling: somewhat afraid	1,419 (17.4%)	1,258 (16.6%)	161 (27.5%)	<i>P</i> < 0.001
Fear of falling: very afraid	474 (5.8%)	368 (4.9%)	106 (18.1%)	<i>P</i> < 0.001
Grip strength (kg)	27.1 (±9.8)	27.2 (±9.8)	25.7 (±10.5)	<i>P</i> = 0.007
TUG time (seconds)	9.2 (±3.8)	9.1 (±3.8)	10.1 (±3.8)	<i>P</i> < 0.001
MoCA	25.0 (23.0–27.0)	25.0 (23.0–27.0)	25.0 (22.0–27.0)	<i>P</i> < 0.001
Orthostatic hypotension	1,063 (13.0%)	973 (12.9%)	90 (15.4%)	<i>P</i> = 0.012

Data presented as mean (±SD) or count (%) or median and (IQR). *P*-value for difference refers to *t*-test for normally distributed variables, Wilcoxon rank sum test for non-normally distributed variables and Pearson's chi-square test for binary variables. IADL = instrumental activities of daily living. Bold font used to highlight statistically significant differences (defined as *p* < 0.05) between groups.

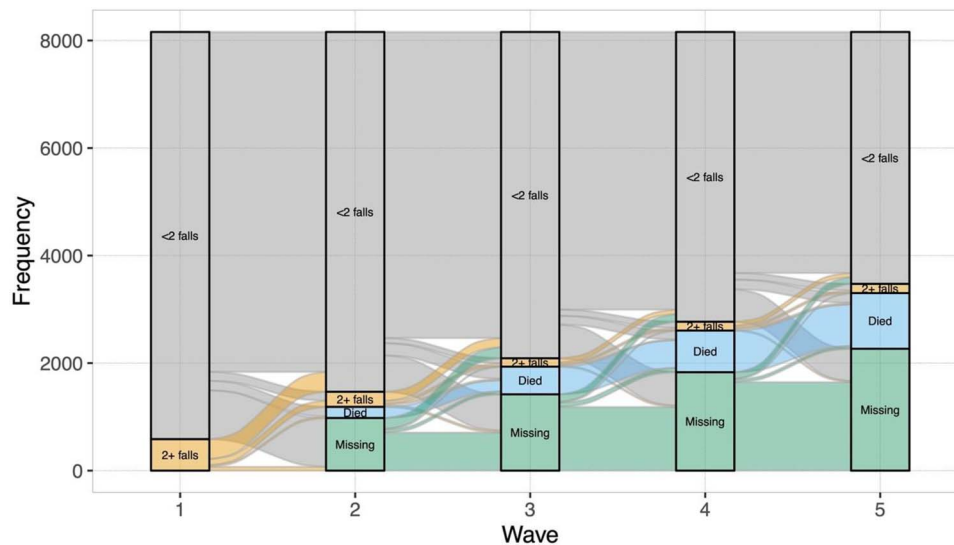


Figure 1. Alluvial chart of the longitudinal transitions of falls states in TILDA (*n* = 8,174).

compared to those who reported no fear. The risk of the transition from ‘one or no falls’ to death increased with greater age, male sex and lower MoCA scores; and the risk of the transition from two or more falls to death increased with higher age, male sex, slower TUG time and reporting being very afraid of falling (compared to those reporting no fear of falling).

The sensitivity analysis of the same multi-state models where missing data were modelled as an additional state is presented in [Appendix S1](#). Compared to the main analysis, the sensitivity analysis transitions between the ‘two or more falls’ category to the ‘one or no falls’ category had a lower

probability of 57% compared to 63%. In the opposite direction the probability was equal at 2%. Transitioning from the category of ‘one or no falls’ to the category of ‘missing’ was 11%, compared to the probability of 13% of moving from ‘two or more falls’ to ‘missing’.

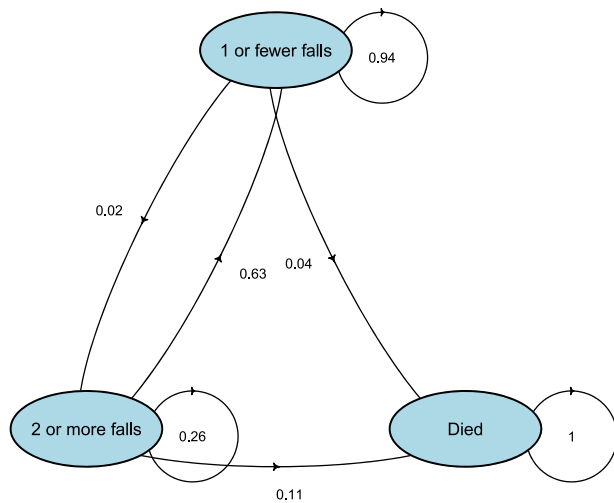
Discussion

This observational study described the 8-year longitudinal trajectories of self-reported falls in TILDA, and the design allowed us to investigate the variables associated with both

Table 2. Hazard ratios and 95% CIs of the estimated covariate effects in multistate model ($n = 8,174$)

	1 or no falls–≥2 falls	1 or no falls–died	≥2 falls–1 or no falls	≥2 falls–died
Sex = female	0.85 (0.66, 1.10)	0.71 (0.56, 0.89)	1.28 (1.03, 1.60)	0.36 (0.17, 0.74)
Age (5-year increment)	1.12 (1.03, 1.20)	1.58 (1.48, 1.69)	1.01 (0.95, 1.09)	1.48 (1.19, 1.85)
Education = secondary	0.95 (0.70, 1.29)	0.86 (0.65, 1.12)	0.92 (0.70, 1.20)	0.83 (0.36, 1.92)
Education = higher	1.07 (0.75, 1.53)	0.74 (0.52, 1.05)	0.97 (0.72, 1.30)	1.52 (0.52, 4.45)
Chronic conditions	1.28 (1.17, 1.40)	1.07 (0.98, 1.16)	1.03 (0.96, 1.11)	1.08 (0.91, 1.28)
MoCA score	0.93 (0.90, 0.97)	0.95 (0.92, 0.98)	0.99 (0.96, 1.02)	0.99 (0.90, 1.08)
TUG (seconds)	0.99 (0.97, 1.01)	1.01 (1.00, 1.02)	0.89 (0.85, 0.92)	1.06 (1.02, 1.11)
Orthostatic hypotension	0.80 (0.58, 1.08)	0.84 (0.62, 1.14)	0.72 (0.55, 0.92)	0.97 (0.39, 2.41)
Fear of falling = somewhat afraid	1.49 (1.10, 2.03)	0.92 (0.65, 1.28)	0.78 (0.61, 1.00)	2.26 (0.74, 6.88)
Fear of falling = very afraid	2.69 (1.76, 4.12)	1.02 (0.53, 1.96)	0.94 (0.66, 1.35)	3.16 (1.03, 9.67)
Antidepressants	1.87 (1.35, 2.59)	1.22 (0.79, 1.88)	0.65 (0.49, 0.87)	0.81 (0.32, 2.05)
Antihypertensives	0.82 (0.61, 1.09)	1.07 (0.83, 1.39)	1.15 (0.89, 1.49)	0.84 (0.37, 1.88)

MOCA = Montreal Cognitive Assessment; TUG = timed up and go. Bold font used to highlight statistically significant hazard ratios.

**Figure 2.** Estimated transition probability for each falls state (from Wave x to Wave $x + 1$) in TILDA.

favourable and unfavourable transitions in falls states. Results demonstrated the dynamic longitudinal nature of falls, even in participants who may be cross-sectionally classified as being 'at high risk'. Indeed, it was evidenced that experiencing two or more falls in one year does not equate to a downwards spiral of more frequent falling; and in fact, the data showed that the most likely scenario (63%) was reporting fewer falls in two years' time, as opposed to continuing to experience recurrent falls (26%) or dying (11%). Awareness of this may help combat stigma associated with falling and promote preventative healthcare-seeking behaviours among community-dwelling older adults who fall. In addition to older age and higher number of chronic conditions, a fear of falling, lower cognitive score and taking antidepressants increased the risk of a negative transition from 'one or no' falls to 'two or more' falls. Whereas, male sex, higher TUG time, the presence of OH and taking antidepressants increased the risk of not having a positive transition in the opposite direction. Altogether, results suggest that improvements in cognitive and psychological status, clinically appropriate psychotropic deprescribing,

mobility, and OH may improve individual falls trajectories. The increased probability of dying before the subsequent wave if reporting two or more falls, and differences observed in Table 1, suggest that it may be appropriate to consider two or more falls as a surrogate marker of frailty.

In a secondary analysis of the MOBILIZE-BOSTON study, Tchalla *et al.* reported 4 falls trajectories in 765 participants over 5 years (no falls [30.1%], cluster falls [46.1%], increasing falls [5.8%] and chronic recurring falls [18.0%]) [31]. Predictors of the 'increasing falls' trajectory were diabetes mellitus and cognitive impairment, and the predictors of the 'cluster falls' trajectory (characterised by falls in first years, but no falls in subsequent waves) were lower gait speed and falls in the past year. Although their groups and analyses are not directly comparable to ours, we too found comorbidity and lower cognitive scores to be associated with deterioration, and higher TUG times to be associated with less likelihood of improvement.

In participants reporting two or more falls in the previous year, the risk of moving to a more favourable state of one or no falls at the next wave was 28% lower for those with OH. This can be interpreted in the light that in community-dwelling older people, OH is a marker of frailty [32], frailty is a predictor of recurrent falls [33, 34], and in much frailer older people (such as those residing in nursing homes), OH has been shown to be an independent risk factor for recurrent falls [35]. However, OH could also be related to underlying morbidities [36] and/or medications [37]. Regarding the latter, our analysis showed that Wave 1 participants who reported two or more falls in the past year were, compared to those reporting one or no falls, more likely to be on antidepressants, but equally likely to be on antihypertensives (Table 1). This mirrors results in Table 2 in that antidepressants were associated with increased risk of negative falls transitions and reduced risk of positive transitions, but antihypertensives had no significant effects on transitions. Whilst antidepressants (together with benzodiazepines and antipsychotics) have been consistently associated with higher risk of falls in older people [38, 39], the risk associated with antihypertensives has been more inconsistent in the literature [29, 30].

With increasing effect size, being somewhat afraid (49%) or very afraid of falling (169%) compared to having no FOF, significantly increased the risk of the negative trajectory from 'one or no falls' to 'two or more falls'. This risk is recognised in the World Guidelines for Falls Prevention and Management for Older Adults, where it is noted that FOF even in the absence of falls in the last 12 months increases the risk of future falls [2]. This is also in keeping with the known interdependent association between late life depression (with or without antidepressant prescriptions), FOF and risk of falls in older people [40]. Other research has pointed to an interactive effect between FOF and mobility limitation and the future falls, which we have not explored in this current study.

Multicomponent exercise programmes and cognitive stimulation (which target potentially modifiable risk factors of this study) may reduce falls in frail community-dwelling older persons at high risk of falls [41]. Yet a recent systematic review found few studies investigating exercises interventions for people with mild cognitive impairment and concluded that there was insufficient evidence to inform clinical practice [42]. Exercise interventions may improve FOF, although there is only low-quality evidence that exercise interventions that cause reduction in FOF reduce the risk of falling [43]. However, cognitive behavioural therapy appears to be effective in reducing FOF and improving balance among older people [44]. Regarding appropriate prescribing for falls prevention, studies have reported moderate success in reducing psychotropic medication use [28], and careful optimisation of psychotropic and non-psychotropic prescriptions can contribute to OH reductions in older people [37]. Given evidence that multifactorial assessment and intervention programmes can reduce the rate [45] and risk [46] of falls, access to these interventions should be promoted and underpinned by an overarching public health message that falling in older people should not be stigmatised as being a sign of inevitable decline and loss of independence.

Limitations

The retrospective self-reported nature of falls is liable to recollection and social desirability bias. Previous research has shown that falls tend to be under-reported when relying on verbal prompts and memory, and under-reporting has been attributed to problems recalling falls, stigma attached to falling and differences in how falls are defined and perceived (e.g. what constitutes 'a fall') [47, 48]. In addition, due to low numbers we did not study more granular transitions in falls subtypes (e.g. injurious, with recalled loss of consciousness) [27]. Our findings may not be generalisable and should be validated in clinical populations and external datasets.

Our study does not explain the causes of falling, and our modelling did not account for the likely presence of interactive effects among covariates. Episodes of frequent falls may cluster around acute stressor events such as periods of acute illness and as health and fitness improves following

these events, so also may the frequency of falls. Attrition of the frailest participants, enhanced fall prevention awareness among returning TILDA participants [49], and/or out-of-study intercurrent clinical interventions may explain the high frequency of favourable transitions. We do not have data on any fall-prevention interventions undertaken by participants.

The recently published World Guidelines for Falls Prevention and Management for Older Adults [2] recommend that individuals with two or more self-reported falls in the previous year are classified as having high risk of falls. Whilst our study followed this classification, being at high risk of falls and falling are not analogous. In practice, those who make a positive transition from having two or more falls in the previous year to one or no falls, should still be assessed for falls prevention interventions.

There was no specific patient and public representative input for this study and we can only hypothesise as to whether an increased awareness of falls trajectories as described in this study would impact the stigma associated with falling. Meaningfully exploring this hypothesis would require a qualitative study.

Conclusion

Whilst the individual and societal costs of falls are significant and justify investment in falls prevention and post-fall risk reduction strategies, we should not forget the negative connotations the label 'faller' can carry for some individuals. Falling does not signal a progressive and inevitable deterioration, and a better clinical and societal understanding of this may help reduce the stigma of falling, and empower older adults who fall (and those who may be at risk) to enact appropriate healthcare-seeking behaviours. Improvements in cognitive and psychological status, psychotropic prescribing, mobility, and OH may improve trajectories of falling.

Data Availability: TILDA provides access to the datasets for research use through anonymised publicly accessible dataset files, and through an on-site Hot Desk Facility. The publicly accessible dataset files are hosted by the Irish Social Science Data Archive based in University College Dublin, and the Interuniversity Consortium for Political and Social Research (ICPSR) based in the University of Michigan. Researchers wishing to access the data must complete a request form, available on either the ISSDA or ICPSR website.

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

Declaration of Conflicts of Interest: None.

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