

RESEARCH ARTICLE

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# Linked versus unlinked hospital discharge data on hip fractures for estimating incidence and comorbidity profiles

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## Abstract

**Background:** Studies comparing internally linked (person-identifying) and unlinked (episodes of care) hospital discharge data (HDD) on hip fractures have mainly focused on incidence overestimation by unlinked HDD, but little is known about the impact of overestimation on patient profiles such as comorbidity estimates. In view of the continuing use of unlinked HDD in hip fracture research and the desire to apply research results to hip fracture prevention, we concurrently assessed the accuracy of both incidence and comorbidity estimates derived from unlinked HDD compared to those estimated from internally linked HDD.

**Methods:** We analysed unlinked and internally linked HDD between 01 July 2005 and 30 June 2008, inclusive, from Victoria, Australia to estimate the incidence of hospital admission for fall-related hip fracture in community-dwelling older people aged 65+ years and determine the prevalence of comorbidity in patients. Community-dwelling status was defined as living in private residence, supported residential facilities or special accommodation but not in nursing homes. We defined internally linked HDD as the reference standard and calculated measures of accuracy of fall-related hip fracture incidence by unlinked HDD using standard definitions. The extent to which comorbidity prevalence estimates by unlinked HDD differed from those by the reference standard was assessed in absolute terms.

**Results:** The sensitivity and specificity of a standard approach for estimating fall-related hip fracture incidence using unlinked HDD (i.e. omitting records of in-hospital deaths, inter-hospital transfers and readmissions within 30 days of discharge) were 94.4% and 97.5%, respectively. The standard approach and its variants underestimated the prevalence of some comorbidities and altered their ranking. The use of more stringent selection criteria led to major improvements in all measures of accuracy as well as overall and specific comorbidity estimates.

**Conclusions:** This study strongly supports the use of linked rather than unlinked HDD in injury research. In health systems where linked HDD are unavailable, current approaches for identifying incident hip fractures may be enhanced by incorporating additional evidence-based criteria.

**Keywords:** Comorbidity, Hip fracture, Incidence, Hospital discharge data, Sensitivity and specificity

## Background

Hip fractures are a major injury burden in community-dwelling older people. About 90% of hip fractures occur in people aged 65+ years, with most of these being fall-related and involving community dwellers [1,2]. Initial hospitalisation costs are reportedly high [3-6] and costs of rehabilitation, home nursing, home help and

institutional care can be substantial depending on subsequent functional impairment [6,7]. Patients with a hip fracture have been found to have a higher risk of dying than would be expected up to 20 years following the hip fracture [8,9].

Accurate estimates of hip fracture incidence, as well as reliable descriptions of the demographic, comorbidity and risk factor profiles of patients, are required for hip fracture management and prevention [10]. Hospital discharge data (HDD) are appropriate for this purpose because virtually all hip fractures necessitate hospital

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admission [11]. In health systems where a unique system-wide patient identifier (UPI) is lacking, hospital records refer to specific episodes of care rather than to cases or persons (hereafter referred to as unlinked HDD). To minimise multiple counting, a standard approach for identifying incident hip fractures from unlinked HDD excludes inter-hospital transfers and/or readmissions within 28 or 30 days of discharge [12,13]. Records showing the discharge status as in-hospital death may also be excluded to further minimise multiple counting based on an assumption that patients who die in hospital would have previous hospital admission(s) [14].

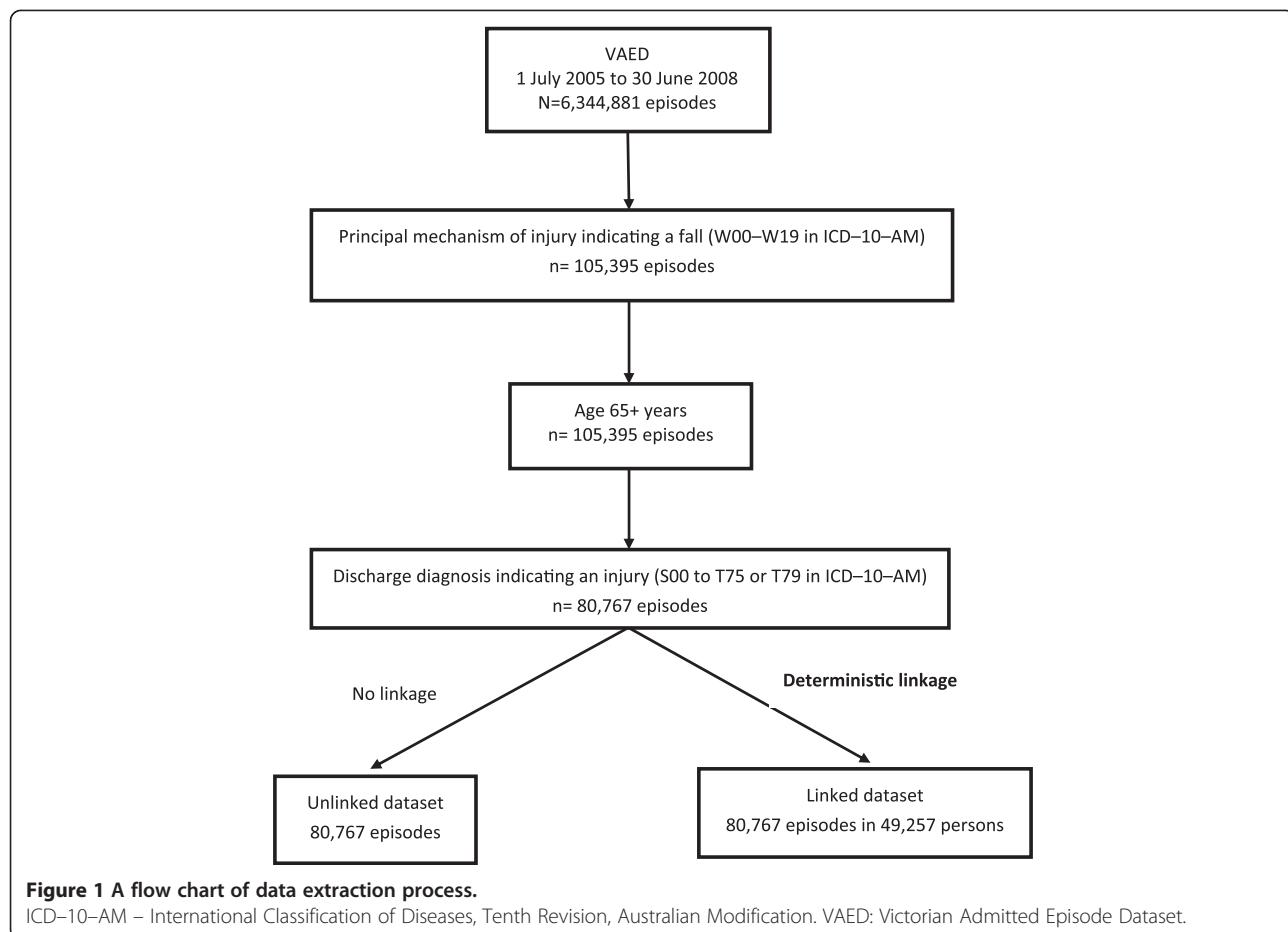
The level of incidence overestimation by unlinked HDD has been estimated to be between 7%–31% by one study which directly compared unlinked HDD with person-identifying (linked) HDD [10]. This overestimation, in turn, would be expected to have a direct impact on the accuracy of patient profiles such as comorbidity, but, to date, little is known about this impact. In view of the continuing use of unlinked HDD in hip fracture epidemiological research [3,5,15], and the desire to apply research results to hip fracture prevention, these data should be assessed for potential inaccuracies in both incidence and comorbidity estimates. The aim of this study was therefore to compare unlinked and linked fall-related HDD to determine the sensitivity, specificity, and negative and positive predictive values of unlinked HDD for estimating fall-related hip fracture incidence and determining patients' comorbidity profiles by using linked HDD as the reference standard. The study focused on community-dwelling older people because the majority of fall-related hip fractures occur in community settings [1].

## Methods

We analysed the Victorian Admitted Episodes Dataset (VAED) between 01 July 2005 and 30 June 2008, inclusive (fiscal years 2005/06, 2006/07 and 2007/08), to estimate the incidence of fall-related hip fracture in community-dwelling people aged 65+ years in Victoria and determine patients' comorbidity profiles. The VAED is an administrative and clinical data collection of admitted patient episodes in acute hospitals in Victoria, Australia's second most populous state [16]. This data collection is managed by the Victorian Department of Health (DOH) and used to support casemix funding, epidemiological research, health services planning and policy development [16]. The collection is subject to regular audits which indicate good-to-excellent diagnosis and procedure coding quality [16,17]. The most recent published audits included, among other diagnoses and procedures, Charlson comorbidities, external cause of falls, hip fracture diagnosis and hip replacement [17].

Each patient within a hospital is identified by a unique, hospital generated patient identifier and each episode has a unique hospital derived episode number; however, the VAED lacks a system-wide UPI and does not capture date of injury information [16,18]. Episodes containing the principal mechanism of injury indicating a fall (W00–W19 in the International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM)) [19,20], the age at admission of 65+ years and the principle diagnosis indicating an injury (S00 to T75 or T79 in ICD-10-AM) [19,20] were extracted from the VAED to form an unlinked dataset. The S00 to T75 or T79 range was specified in order to exclude injuries due to medical care procedures [21]. Figure 1 summarises the data extraction process. The unlinked dataset was internally linked by the DOH using stepwise deterministic linkage and person-identifying variables (such as sex, date of birth, country of birth, postcode, and Medicare number and suffix) to produce a linked dataset for the present study [22]. The linkage process and linkage quality have been described in detail elsewhere [22]. Briefly, this process consists of nine steps, including standardisation of linkage variables, determination of the quality of coding and quality assessment of linked data [22]. A DOH study on the quality of VAED internal linkage for the period 1995–2000 found that the quality of coding was high and the false positive rate, defined as the rate of incorrectly matched records, was low (between 1% to 2%) [22]. However, the report indicated that the false negative rate, measured as the percentage of unmatched inter-hospital transfer records from the same patients, was high (15%). A more recent assessment of the quality of VAED internal linkage is not publicly available.

Within the unlinked dataset we used a standard approach of identifying incident fall-related hip fractures [14] (hereafter referred to as the base case) (Table 1)—records were selected if the principal diagnosis was hip fracture (S72.0 to S72.2 in ICD-10-AM [19,20]), the admission source was coded as “private residence/accommodation” and the discharge status was other than in-hospital death. The category “private residence/accommodation” includes people living in their own home or private accommodation and excludes residents in nursing homes [16]. We excluded records indicating readmission within 30 days of discharge; however, given the lack of a UPI in the VAED and the lack of a hospital site identifier for private hospitals this was only possible for patients admitted to the same public hospitals during the study period (64.7% of patients according to the linked dataset). Patients admitted to the same public hospitals during the study period were significantly younger (median age 76 years; interquartile range ((IQR) 60–84) than those admitted to different public hospitals during



**Figure 1** A flow chart of data extraction process.

ICD-10-AM – International Classification of Diseases, Tenth Revision, Australian Modification. VAED: Victorian Admitted Episode Dataset.

**Table 1** Selection criteria for linked and unlinked Victorian Admitted Episodes Dataset

	Reference standard	Base case	S1	S2	S3	S4
<b>Inclusion criteria</b>						
Principal diagnosis hip fracture*	✓	✓	✓	✓	✓	✓
Admission source coded as "private residence/accommodation"	✓	✓	✓	✓	✓	✓
<b>Exclusion criteria</b>						
Readmission within 30 days of discharge	✓	✓	✓	✓	✓	✓
Readmission within 120 days of discharge	✓			✓	✓	✓
Discharge status denoting in-hospital death		✓	✓	✓		
Hip revision procedures only	✓			✓	✓	
Non-acute care type	✓			✓	✓	
Non-emergency admission	✓			✓	✓	

S1 – Scenario 1. S2 – Scenario 2. S3 – Scenario 3. S4 – Scenario 4.

\* S72.0–S72.2 in International Classification of Diseases, Tenth Revision, Australian Modification.

the study period (median age 81 years; IQR 72–86) (non-parametric equality-of-medians test  $p < 0.001$ ).

For the linked dataset, we used the same principal diagnosis range and admission source category as those for unlinked data, but disregarded discharge status. We further refined our identification by including only records showing emergency hospital admission for acute care with no hip revision procedure code(s) (Table 1) [15]. Due to the lack of date of injury in the VAED [18], the lack of ICD-10-AM codes on laterality of fractures (Saad P. Disease classification developer, National Centre for Classification in Health (Australia). Personal communication. 30 April 2010) and the inaccuracy of fracture type classification [23], we developed additional criteria to distinguish between the first and subsequent fall-related hip fracture in the same patients. We assumed, based on a literature review, that the minimum time gap (clearance period) between incident fall-related hip fractures in the same patient would be 120 days [24,25] and that all principal external cause codes (mechanism of injury, place of occurrence and activity being undertaken when injured) would differ between different fall-related hip fractures in the same patient. We also performed the

analysis without the criterion for external cause codes; however, we found only seven cases that would be identified as incident cases if we omitted this criterion.

We defined the method of identifying incident fall-related hip fracture from linked data as the reference standard and calculated the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for the base case using standard definitions [26]. We conducted a sensitivity analysis of the base case under four scenarios (Table 1)—S1 included records showing the discharge status as in-hospital death; S2 excluded records indicating readmission within 120 days of discharge; S3 excluded records indicating readmissions within 120 days of discharge, records with only hip revision procedure code(s), and those with the care type coded as non-acute and the category of admission coded as non-emergency; S4: was the same as S3 but also included records showing the discharge status as in-hospital death (i.e. S4 employed the same selection criteria as the reference standard).

We calculated age-specific hospital admission rates for fall-related hip fracture in community-dwelling people aged 65+ years using Victorian population estimates for relevant years [27–30]. The denominator for each age group was obtained by subtracting the number of residents in nursing homes from the population estimate for this group. We directly standardised rates of hospitalisation to the 2001 Australian standard populations [31].

Patients' comorbidities were classified using the Deyo adaptation of the Charlson Comorbidity Index (CCI) because this index was constructed using administrative data similar to those collected for the VAED, and validated using the VAED [32]. We also estimated the prevalence of other risk factors for falling and fall-related fractures, including osteoporosis, Parkinson's disease, visual impairment, deafness and delirium, using ICD-10-AM codes also tested on the VAED [33]. We distinguished comorbidities from adverse events that

arose during hospitalisation by utilising a condition-onset flag available in the VAED [16]. The extent to which comorbidity prevalence estimates by unlinked data differed from those by linked data was assessed in absolute terms by performing pairwise comparisons. For patients in the linked dataset with more than one hospitalisation for a fall-related hip fracture, we optimised comorbidity ascertainment by defining the first multiday record as the index hospitalisation and searching this record as well as looking back at previous record(s) for the presence of comorbidities (hereafter referred to as lookback) [34]. Comorbidity was deemed to be present if it was coded in one or more of these records. The median period of lookback was 565 days (IQR 274–836).

The Monash University Human Research Ethics Committee granted approval for this study. We conducted all analyses in Stata version 10 [35]. We evaluated equality of proportions using two-sample chi square tests of proportions or Fisher's exact test, as appropriate. For skewed continuous variables, we compared medians using nonparametric K-sample tests on the equality of medians [35]. A multivariable Poisson regression model controlling for age and sex was used to assess the existence of a trend in fall-related hip fracture hospitalisation rates over time. All tests were two tailed. The level of significance was 5%.

## Results

A total of 10,110 incident fall-related hip fractures in 9,879 community-dwelling older persons were identified from the linked dataset (Table 2). Of these patients, 2.3% had a second fall-related hip fracture; the median time from the first to second fall-related hip fracture admission was 335 days (IQR 216–551 days). No patients had more than two fall-related hip fractures.

Overall, the base case performed less well compared with the reference standard and the other scenarios tested (Table 2). The inclusion of hospital records showing the discharge status as in-hospital death (S1)

**Table 2 Sensitivity, specificity, positive and negative predictive values of unlinked data in identifying incident fall-related hip fractures**

	Linked data Ref standard	Unlinked data Base case	Unlinked data Scenario 1	Unlinked data Scenario 2	Unlinked data Scenario 3	Unlinked data Scenario 4
No hip fractures	N=10,110	N=11,110	N=11,746	N=11,056	N=10,173	N=10,765
Overestimation	NA	9.9%	16.2%	9.4%	0.6%	6.5%
Sensitivity		94.4% (94.0–94.9)	99.8% (99.7–99.9)	94.4% (93.9–94.8)	94.4% (93.9–94.8)	99.7% (99.6–99.8)
Specificity		97.5% (97.4–97.6)	97.4% (97.2–97.5)	97.6% (97.5–97.7)	99.0% (98.9–99.1)	98.9% (98.8–99.0)
PPV		85.9% (85.3–86.6)	85.9% (85.2–86.5)	86.3% (85.7–87.0)	93.8% (93.3–94.3)	93.7% (93.2–94.1)
NPV		99.1% (99.0–99.2)	100.0% (99.9–100.0)	99.0% (99.0–99.2)	99.1% (99.0–99.2)	100.0% (99.9–100.0)

Note values are percentages (95% confidence intervals) unless stated otherwise. True negatives were community-dwelling Victorian population aged 65+ years hospitalised for fall-related injury other than a hip fracture between 2005/06 and 2007/08.

NA – Not applicable. PPV – Positive predictive value. NPV – Negative predictive value. CI – confidence intervals.

produced the highest sensitivity (99.8%) and NPV (100.0%) while maintaining specificity and PPV. Extending the clearance period from 30 to 120 days (S2) marginally reduced the number of cases and improved PPV slightly. The application of additional selection criteria to S2 (exclusion of records showing hip revision procedure(s) only and records having the care type coded as non-acute or having the admission category coded as non-emergency) to create S3 resulted in the highest specificity (99.0%) and PPV (93.8%) while maintaining sensitivity and NPV. Using selection criteria identical to those in the reference standard improved all measures of accuracy in S4 compared with the base case. We found S4 to be more sensitive than S3 while being similar in most other accuracy measures. Scenario S3 was as sensitive as S1.

The age-adjusted fall-related hip fracture hospital admission rate per 100,000 population dropped from 520.6 in 2005/06 to 511.2 in 2006/07 and 492.6 in 2007/08 according to the linked dataset. These downward trends over time were not consistently statistically significant ( $p > 0.05$  for the decline between 2005/06 and 2006/07, and  $p < 0.05$  for the decline between 2005/06 and 2007/08 and between 2006/07 and 2007/08). However, we observed a statistically significant trend toward higher hospital admission rates in older age groups in both men and women (all  $p < 0.001$ ). Women outnumbered men in every age category.

Although age-specific and age adjusted/standardised hospital admission rates differed across all methods, gender distributions did not vary significantly between datasets, rates in the 65–69 and 70–74 age groups were broadly similar between datasets, and the statistically inconsistent downward trends across time observed in the linked data was also seen with the unlinked data. The median age at admission, sex distribution, marital status and Indigenous status were also similar across datasets. In Australia, the Indigenous status of patients is obtained through self-identification. An assessment of the accuracy of Indigenous status in Victorian HDD for 2001/02 reported a 22% underestimation rate [36].

According to the linked data the prevalence of any Charlson comorbidity was 31.1% and the prevalence of any Charlson or non-Charlson comorbidity was 37.3% (Table 3). The most common comorbid conditions among patients were renal disease (7.6%), dementia (7.1%), congestive heart failure (5.7%), diabetes (5.4%), diabetes with complications (5.3%), and pulmonary disease (4.3%). The least prevalent comorbidities were neuropathy (<5 cases), liver disease (mild, moderate and severe 0.2% in total), peptic ulcer (0.2%), ataxia (0.1%) and human immunodeficiency virus (0.0%).

Trends towards lower comorbidity prevalence estimates by unlinked data were observed; however, differences between these estimates and those by linked data were not consistently statistically significant across all

**Table 3 Comorbidities in community-dwelling older people hospitalised for fall-related hip fracture by data source**

Comorbidity	Linked data Ref standard	Unlinked data Base case	Unlinked data Scenario 1	Unlinked data Scenario 3	Unlinked data Scenario 4
Any comorbidity	37.3 (36.3–38.2)	30.7 (29.8–31.5)	32.0 (31.2–32.9)	31.2 (30.3–32.1)	32.6 (31.7–33.5)
Diabetes	5.4 (4.9–5.8)	4.4 (4.0–4.8)	4.5 (4.1–4.9)	4.5 (4.1–4.9)	4.5 (4.1–4.9)
Diabetes complications	5.3 (4.8–5.7)	4.2 (3.8–4.6)	4.4 (4.1–4.8)	4.3 (3.9–4.7)	4.5 (4.1–4.9)
Renal disease	7.6 (7.1–8.1)	5.8 (5.4–6.3)	6.5 (6.1–7.0)	6.0 (5.5–6.5)	6.7 (6.3–7.2)
Dementia	7.1 (6.6–7.6)	5.6 (5.2–6.1)	5.8 (5.3–6.2)	5.8 (5.4–6.3)	6.0 (5.6–6.5)
Congestive heart failure	5.7 (5.3–6.2)	4.0 (3.6–4.4)	4.8 (4.4–5.2)	4.1 (3.7–4.5)	4.9 (4.5–5.3)
Pulmonary disease	4.3 (3.9–4.7)	3.2 (2.9–3.6)	3.6 (3.2–3.9)	3.3 (3.0–3.7)	3.6 (3.3–4.0)
Osteoporosis	3.9 (3.5–4.3)	4.3 (3.9–4.7)	4.3 (3.9–4.6)	4.4 (4.0–4.8)	4.3 (3.9–4.7)
Parkinson's disease	3.0 (2.7–3.3)	2.7 (2.5–3.1)	2.7 (2.4–3.0)	2.7 (2.4–3.0)	2.7 (2.4–3.0)
Delirium	2.6 (2.3–2.9)	1.8 (1.6–2.1)	1.9 (1.7–2.2)	1.9 (1.7–2.2)	2.0 (1.8–2.3)
Cerebral vascular accident	2.2 (1.9–2.5)	1.6 (1.4–1.9)	1.6 (1.4–1.9)	1.7 (1.4–1.9)	1.7 (1.4–1.9)
AMI	2.0 (1.7–2.2)	1.3 (1.1–1.5)	1.5 (1.3–1.7)	1.3 (1.1–1.6)	1.5 (1.3–1.8)
Cancer	1.8 (1.6–2.1)	1.5 (1.3–1.8)	1.6 (1.4–1.9)	1.5 (1.3–1.7)	1.6 (1.4–1.9)
Vision impairment	1.7 (1.5–2.0)	1.3 (1.1–1.5)	1.3 (1.1–1.5)	1.3 (1.1–1.6)	1.3 (1.1–1.5)
Deafness	1.4 (1.2–1.7)	1.0 (0.8–1.2)	1.0 (0.8–1.2)	1.0 (0.8–1.2)	1.0 (0.9–1.3)
Paraplegia	1.3 (1.1–1.5)	0.9 (0.8–1.1)	0.9 (0.8–1.1)	1.0 (0.8–1.2)	1.0 (0.8–1.1)

Note values are percentages (95% confidence intervals) unless stated otherwise. Results for Scenario 2 are identical or almost identical to those in the base case and hence not shown here. Prevalence <1% not presented (metastatic cancer, peripheral vascular disease, peptic ulcer, liver disease, severe liver disease, ataxia, human immunodeficiency virus and connective tissue disorder).

AMI – Acute myocardial infarction.

unlinked vs. linked comparisons, except for the prevalence of any comorbidity and the prevalence of dementia ( $p$ -values <0.001 and <0.05, respectively). The S4 selection method performed better than the base case and other scenarios in having the least number of comorbidities whose prevalence was significantly different from that estimated by linked data.

The top three comorbidities and their ranking were the same irrespective of the data source and case selection method: these included (in descending order) diabetes (with or without complications), renal disease and dementia. These three comorbidities accounted for approximately 55.0% of comorbidities in the hip fracture patients according to the linked data. Similar estimates (54.3%–55.3%) were obtained from the unlinked data. Nevertheless, the data sources did not agree on the fourth and fifth most common comorbidity. Osteoporosis was identified as either the fourth or fifth most common comorbidity among incident cases by methods using the unlinked data but was not rated in the top five comorbidities by the linked data. The reverse was found for pulmonary disease. Another difference between the linked and unlinked data was that the former showed gender differences in the prevalence of osteoporosis with a female to male ratio of 6.6 ( $p$  <0.001) but not the latter ( $p$  >0.30 for all methods using the unlinked data).

## Discussion

Methods of estimating fall-related hip fracture incidence in community-dwelling older people using unlinked HDD overestimated fall-related hip fracture incidence, underestimated the prevalence of some co-morbid conditions in patients and altered the relative ranking of the top five comorbidities. To our knowledge, this is the first study to concurrently assess the accuracy of both incidence and comorbidity estimates in the comparison of linked with unlinked HDD. Two similar comparison studies have been conducted but they were only incidence studies; one study examined the incidence of hospitalised injurious falls and results for hip fracture were not reported separately [12] whereas the other study focused on hip fractures and our estimates of incidence overestimation by the base case and its variants are within the range of estimates reported by this study [10]. Our results support earlier recommendations that linked rather than unlinked HDD be used in injury incidence estimation and provide further rationale for these recommendations by describing comorbidity differences between these two data sources.

In health systems where linked HDD are unavailable, S4 appears to be the most promising method. The use of the most stringent selection criteria in S4 led to major improvements in all accuracy measures as well as demographic estimates, and overall and specific comorbidity

estimates. These criteria would be simple and easy to implement if an unlinked data source has admission and care details similar to those contained in the VAED.

Our estimate of the prevalence of any Charlson comorbidity, and for specific Charlson comorbidities (except dementia and diabetes with or without complications) using linked data is lower than previously reported [9,37]. The underestimation of comorbidity prevalence by linked data in our study may be attributed to the fact that we ascertained patient comorbidity from HDD instead of chart review. It is commonly acknowledged that HDD tend to underestimate comorbidity prevalence [38]. The lower comorbidity estimates in our study may also be explained by the fact that up to 30% of patients included in recent studies [8,9,37] were from nursing homes; these patients would have had a higher comorbidity burden than community-dwelling older people in our study.

Very few published hip fracture studies have reported fall and fracture risk factors in patients alongside Charlson and non-Charlson comorbidities. Our estimate of 3.9% for osteoporosis based on linked data is slightly higher than that based on self-reported data on the Australian adult population (3.0%); however, the female-to-male ratio is similar [39,40]. The discrepancy in the prevalence of osteoporosis may be explained by differences in the age distribution in our study and the adult population. The prevalence of visual impairment in patients identified by the linked data (1.7%) is considerably lower than those reported for older Australians (4.7% in 60–69 years, 11.1% in 70–79 years and 28.7% in 80+ years) [41] suggesting that visual factors may not be routinely assessed in hip fracture patients. Another possible explanation is that visual factors may be assessed routinely but not recorded or coded in HDD.

The annual number and age-standardised rate of fall-related hip fractures per 100,000 population have been proposed for inclusion in a set of fall injury outcome metrics for use when evaluating progress in fall prevention programs for older people [42]. Our study has demonstrated that although incidence estimates based on unlinked HDD (except S3) are biased upward due to multiple counting, they appear to be suitable for monitoring sex differences and trends across time.

The absence of date of injury information in the VAED made it difficult to distinguish multiple admissions for the same fall-related hip fracture from new admissions associated with a recurrent fall-related hip fracture. Our strategy for dealing with this problem was to use a clearance period based on a literature review in conjunction with information from combinations of variables. Our clearance period compares favourably with the observed window of time during which the risk for a recurrent hip fracture is highest [24,25], and is consistent with the

timeframe during which the risk of readmission is high [43,44]. Furthermore, our estimate of the incidence of a second fall-related hip fracture is consistent with estimates reported in the literature [45]. Our evidence-based criteria for identifying incident fall-related hip fractures from linked HDD in the absence of the date of injury were recently validated against a gold standard which used the date of injury and found to be highly accurate (unpublished study).

Our study, however, has some limitation which must be acknowledged. The category of patients in the VAED used to represent community-dwelling people includes people from prisons, armed forces base camps/hospitals, supported residential facilities (excluding nursing homes) and special accommodation houses. Some of the patients included in our datasets were likely to have resided in one of these facilities prior to hospitalisation; however, the VAED does not contain supplemental information to complement descriptions of accommodation categories. Nevertheless, this classification error is non-differential; therefore, it should not impact on our study findings.

Finally, the lookback study we conducted was not comprehensive because we only had access to patients' previous hospitalisation records if these were fall-related. In addition, episodes of care that started or concluded at the beginning of the study period would have had no prior records in our dataset. This could be another contributing factor to the lower comorbidity estimates based on linked data in our study.

## Conclusions

Methods of estimating fall-related hip fracture incidence in community-dwelling older people using unlinked HDD overestimate fall-related hip fracture incidence, underestimate the prevalence of some comorbid conditions and may alter the relative ranking of these conditions. These results re-enforce earlier recommendations that linked rather than unlinked HDD be used in injury research. The utility of linked HDD would be enhanced by the inclusion of the date of injury. In health systems where linked HDD are unavailable, current approaches for identifying incident hip fractures may be enhanced by incorporating additional evidence-based criteria.

## Competing interests

The authors declared that they have no competing interest.

## Authors' contributions

TV conceived and planned the study, applied for ethics approval, obtained hospitalisation data, defined and performed the statistical analysis, and drafted the manuscript and coordinated the contribution from CFF and LD. CFF and LD contributed to the conception, interpretation of data and critical appraisal of the manuscript. All authors read and approved the final manuscript.

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