ARC Centre of Excellence in Population Ageing Research

Working Paper 2018/11

Direct Estimation of Life Expectancies and Transition Rates of Residential Care Residents

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ABSTRACT

Aged care residents, residential care developers and government policy-makers need accurate information on likelihood of main events in residential care (i.e. residents' functional decline and death). Since 20 March 2008 Australian government subsidies for residential care have been based on detailed assessments of individual care needs, and this generated 1.5 million assessment records by 30 June 2015. Four levels are assessed for three types of need - aids to daily living, behavioural needs, and complex health care. Logistic regression models are used to derive mortality and transition probabilities from these data. Backwards derivation was used to estimate mean life expectancies from these models, and microsimulation used to model distributions around means. As there has been continuing drift in assessed care needs, the mortality and transition assumptions estimates are based on the most recent year of experience. A microsimulation model of aged care residents, with all residents at 30 June 2015 as the initial population, has been constructed.

Key Words: ADL, Assistance needs, Life expectancy, Residential care, Australia

Introduction

Assistance needs of persons in residential aged care change over time. Changes are usually one-directional, leading to a functional decline and increased requirements for high-level assistance provision (Holroyd-Leduc et al. 2004). A substantial body of literature as demonstrated that functional abilities of aged care residents deteriorate under the influence of various chronic diseases (Broad et al. 2011; Martikainen et al. 2009; Binder et al. 2003; Flacker & Kiely 1998; Barker et al. 1998) most of which are associated with a higher risk of nursing home placement (Porock et al. 2010; Ang et al. 2006). Age-related decrease in muscle strength, cardiovascular function or neuromuscular response times (Fiatarone-Singh & Mayer 2002; Rajeski & Mihalko 2001) also contribute to functional deterioration.

Disease progression, comorbidities and functional decline affect life expectancy of nursing home residents. Research evidence suggests that life expectancy in residential care is associated with age, sex, functional impairment, ADL performance, cognitive disability, low body mass index, medical frailty, poor nutrition and having diseases such as diabetes, respiratory infections, or congestive heart failure (Shah et al. 2013; Hjaltadottir et al. 2011; Dale et al. 2001).

Predicting life expectancy in residential care may appear controversial (Got et al. 2011) but it is an increasingly important issue (Heppenstall et al. 2015). When provided at a high level and over a long period, residential care is costly and labour-intensive. If planning is not done properly, such activity strains the aged care workforce and the ability of workers to provide adequate care. Proper care planning is also important for care residents. Research evidence has shown that communicating with residents about their prognosis may assist them in planning and avoiding unnecessary hospital admissions and treatments (Dying Matters 2012). Life expectancy estimates help not only financial planning by residents and their families, but also can assist care providers to achieve a resident mix best suited to their staff and facilities.

Personal wellbeing of care residents, future workforce planning and costs estimation altogether can benefit from having accurate information on life expectancies and the dynamics of change in residents' care needs. The most important elements of information about 'inside-of-care' system are care needs, transition probabilities and duration of stay. All of these are recorded in the Aged Care Funding Instrument (ACFI) unit records (AIHW 2015a). These data are generated through the assessments that are made soon after entry to residential care, and repeated as health changes occur. Once an ACFI rating has been received, mean life expectancies vary from 7 months to 7 years (AIHW 2015b), although individuals can live for much less or more than these means.

The ACFI assistance needs are used by the Australian Government to determine the subsidies for residential aged care providers to support care needs of the residents (Department of Health, 2015). The time spent in care with a certain set of assistance needs determines the final amount of the subsidy for a resident. Residential subsidy payments are clinically based on four levels for each of three domains - aids to daily living (ADL), behaviour (BEH) and complex health care (CHC).[1] Having a specific combination of assistance needs, such as being assessed as the highest in all 3 domains, also affects the nature of care provision. Therefore, both the providers

[1] The ACFI instrument has two diagnostic sections (recording up to three mental or behavioural diagnoses and up to three other medical diagnoses), and its questions provide basic information that is related to fundamental care need areas, it is not a comprehensive assessment tool. Prior to 1 July 2014, the instrument determined an initial classification for overall care needs (high or low care) and a subsidy level relevant to them (AIHW 2015a).

and the Government are interested in knowing how long residents are expected to stay within specific combination of care assistance domains and what is the probability that these domains change.

Australian authors have provided evidence that the ACFI assistance needs are good predictors of exit from residential care, that their level increases with time spent in care and that assistance needs may be used to determine life expectancy in residential care (Jukic & Temple 2017). This paper broadens our understanding of functional decline in residential care by answering the following research questions*: What is the life expectancy in residential care for residents with a particular combination of care needs* and *how residents' assistance needs change with age and time spent in residential care?*

The aim in this paper is to model deaths, and transitions between needs levels, for persons in residential aged care in Australia. Essentially, there are two steps:

- First, using a longitudinal file of 1.05 million ACFI ratings from the National Aged Care Data Clearinghouse (NACDC), we estimate transitions from different combinations of care assistance needs and construct statistical models to predict the occurrence of such changes.
- Second, we estimate life expectancies of aged care residents.

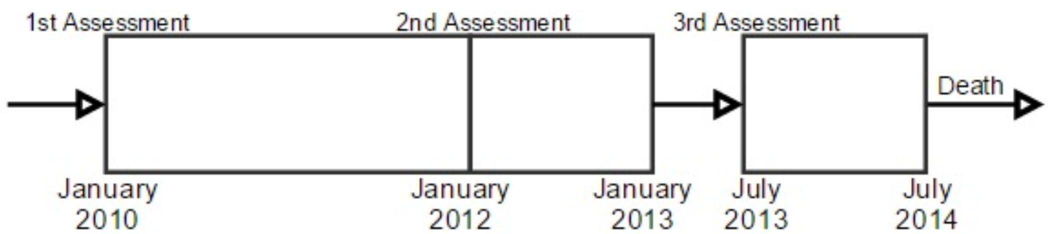
Data

Data used in this paper come from the National Aged Care Data Clearinghouse (NACDC) of the Australian Institute of Health and Welfare (AIHW). A longitudinal file of 1.05 million ACFI ratings (AIHW 2016) contained a record of every ACFI assessment for each permanent care resident in the period between 20 March 2008 (introduction of the ACFI system) and 30 June 2015 (more details in 2.3.3 '*ACFI Longitudinal Data*'). These ACFI appraisals provided full information on the assistance needs in the three main domains: the daily living (ADL), the behaviour (BEH) and the complex health care (CHC). Each domain is measured at the scale from 0 to 3, with '3' being the highest level of assistance needs and '0' requiring no assistance at all (Department of Health 2013).

This comprehensive longitudinal data set captured each person's pathway inside the residential care system, including multiple assessments, temporary discharges to other care facilities, discharges to hospital, re-entries and modes of permanent exit from nursing home. Longitudinal data give high quality information that does not suffer from rising non-response rates, attrition and under reporting (Productivity Commission 2013), enabling the detection of changes in the features of the target population (IWH 2015). Permanent aged care residents, as the population of interest, undergo the assessments that may or may not change their recorded dependence levels. The sequence of such changes in care-need levels captured in the longitudinal ACFI data enables the direct estimation of transitions between combinations of assistance needs, together with eventual death. Transitions and deaths are the two crucial components that enable estimation of the life expectancy in residential care.

Several data challenges had to be tackled in preparation for the transition and life expectancy analyses. These problems include dealing with duplicate records, multiple and overlapping care episodes and inconsistencies around the start and the end of assessments. For example, discontinued unit records increase the complexity of the longitudinal analyses. Figure 1 shows a discontinued record of a person entering residential care in January 2010, receiving a revised ACFI assessment in January 2012, leaving the facility in January 2013, re-entering residential care in July 2013 with a new ACFI assessment, and dying in July 2014. Furthermore, some aged care episodes are transposed in the data, with the first admission and separation recorded as the second episode for the person, not the first. Such cases were re-sequenced to avoid bias in the life expectancy and transition rate estimates.

Figure 1. An example assessment cycle for a hypothetical unit record



To put the data in adequate form for methodological procedures, a few assumptions had to be made. For instance, personal cases with an exit from a nursing home followed by a re-entry after some months were treated as a continuous episode, with the domain values (ADL, BEH & CHC) at their last assessment. Other assumptions and data corrections include:

- Of the 1,052,887 records of ACFI assessments supplied, two had no entry dates, and were omitted;
- One person had no sex recorded, and was assumed to be female;
- Eight had no birth dates, and were assumed to have entered at age 84 (average entry age);
- 12,256 had the same assessment start and end dates, and were omitted;
- 33,664 had assessment start dates differing from the end date of their previous assessment, and the end date was changed to match the subsequent start date. Most of these cases had a start date a few months after the end date for the previous assessment.

Methods

Transition probabilities between all possible combinations of care assistance needs and monthly probabilities of death were analysed using a stepwise logistic regression (as described in Hosmer & Lemeshow 2000 p. 116). For example, we calculated the probabilities that a care resident with ADL1, BEH1 and CHC1 develops higher assistance needs (i.e. ADL2, BEH2 and CHC2). In total, our approach led to 36 logit models of the following form:

$$\log(odds) = \beta_0 + \beta_1 * x_1 + \cdots + \beta_n * x_n \qquad \text{[Eq. 1]}$$

where β refers to the estimated parameters (coefficients) and x_i represents the independent variables (age, care needs levels in 3 domains, year). The log $(odds)$, or log of the odds ratio, is defined as $\ln\left[\frac{p}{1-p}\right]$. It expresses the natural logarithm of the ratio between the probability that an event of transition to different care needs level will occur, $P(Y = 1)$, to the probability that an event will not occur, $P(Y = 0)$. It is noteworthy that the model estimates (β) express the relationship between the independent and dependent variable on a log-odds scale. A coefficient of 0.030 would thus indicate that a one-unit increase in β_i is associated with a log-odds increase in the occurrence of the transition Y of 0.030. To get a clearer understanding of the constant effect of a predictor on the likelihood that an outcome will occur, odds-ratios can be calculated. This can be expressed as:

$$\text{odds(Y)} = exp^{\beta\_0+\beta\_1*x\_1+\cdots+\beta\_n*x\_n} \qquad \text{[Eq. 2.]}$$

which is the exponentiated model. Alongside the odd-ratio, we also show predicted probabilities of the selected transitions between care needs (Y) at specific values of key predictors in the form of the following equation:

$$p = \frac{1}{1+exp^{-z}} \qquad \text{[Eq. 3]}$$

where z refers to the $log(odds)$ regression equation. The same logistic regression method is also used to derive the monthly probability of death models.

The transitions and deaths are weighted to enable easier computation of the logistic models. For example, all the transitions between one specific combination of care assistance needs to another combination were grouped. Figures 3-5 show such aggregates for each of the main assistance domains separately.

The transition analyses relied on a few assumptions. Firstly, the cases who exit from residential care and then re-enter are treated as continuously being in residence with the domain values at their last assessment. Secondly, the likelihood that changes in two or three domains will occur at the same time, rather than independently, were ignored. Finally, the assumption was made that anyone who exited a nursing home but did not re-enter died at the date of exit.

Deaths

Logistic regression was used to fit models of monthly mortality rates. The three sets of independent variables used were:

- Age, sex, year, and dummy variables for the three highest levels of ADL, BEH and CHC
- Age, sex, year and dummy variables for the presence of different diseases
- Age, sex, year, and all the needs and disease dummy variables.

In each case, backwards stepwise regression (Hosmer & Lemeshow 2000 p. 116) was used to retain only those variables significant at the 5% level. Analyses were made using all 6 available years of data, and then only using the most recent year of data.

Transitions

Logistic regression was used to fit monthly transition probabilities between each ADL level. These transitional probabilities were conditional, in that they assumed no death had occurred in the month. The independent variables used for transitions between ADL levels were age, sex and dummy variables for the three highest levels of BEH and CHC. Similarly, the independent variables used for transitions between BEH and CHC levels were dummy variables for the three highest levels of the other domains. Analyses were made using only transition data from June 2014 to May 2015. Independent variables were included in transition models only if they were significant at the 5% level. Probabilities of remaining at a level were taken as 1 less the sum of the estimated probabilities of changing levels.

Life Expectancies

The life expectancy program assumes monthly transition rates, with the backwards estimation approach. For example, the life expectancy at month x when in state i, (notation $E_{x,i}$), was calculated as:

$$E_{x,i} = q_{x,i} \,/\, 24 \,+\, (1 - q_{x,i}) \times \sum Pr_{(x,i\ to\ j)} \times [\, E_{(x+1,j)} + 1/12)] \qquad \text{[Eq. 4.]}$$

where $q_{(x,i)}$ is the probability of exit from state i between month x and $x+1$ and $Pr_{(x,i\ to\ j)}$ is the probability of transition from state i to j between month x and $x+1$, where the summation is over the 64 possible values of j. In applying this equation, life expectancies were assumed to be 0 at age 115. A more exact version of this relationship is used in the construction of the Australian Life Tables 2010-12 (Australian Government Actuary 2014). The formula 7.4 closely reproduces the published life expectancy values across the whole age range.

The life expectancy program uses monthly transition rates. These are more accurately derivable than annual rates, as competing forces become less of a problem, and no incomplete records are lost. To derive monthly rates, the ACFI data were transformed, with each record now showing the values for each domain in one month, and their values in the next month if exit did not occur in the month.

In operational terms, our logistic analyses were conducted in the STATA 13 software (StataCorp 2013) and were cross-checked in the R software package "pscl" (Jackman 2015), including the model diagnostics. The life expectancy is calculated in C# (Microsoft Corporation 2013).

Limitations

The research approach used here has several limitations. For confidentiality reasons, all entry, assessment and exit dates were supplied to us as months and years, birthdates as years, and no geographic or facility data were supplied. Despite the limitations, the methods and data analysis proposed here represent a major advance on current research practice, offering the prospect of vastly increasing knowledge about the residential aged care system in Australia. The system dynamics are thoroughly examined using advanced quantitative tools, including transitions between the states, exit probabilities and life expectancy estimates. Such measures can better inform policy and practice, providing relevant and timely information. Systematic application of the methods proposed here can establish the evidence base and thereby increase the quality and efficiency of residential care.

Results

Changes in the ACFI system

The ACFI classification system was introduced on 20 March 2008, and by 30 June 2009 most of the residents had ACFI assessments. The growth in total numbers of persons with ACFI appraisals shown in Table 1 therefore largely reflects the increases in persons in residential aged care. A new combined assets and income test applied to entrants from 1 July 2014 and this resulted in unusually high numbers of entrants in 2013-14. The processing delays associated with this new test resulted in unusually high numbers of persons in respite care at 30 June 2015 with fewer persons in permanent residential care. Administrative changes such as the new combined assets and income test can have large short-term effects on statistics such as those in Table 1. Because of some recent residents not having received ACFI ratings, and some data adjustments, the total number of persons at 30 June 2015 in the table is about 1.4% below the actual total.

Table 1. Characteristics of persons with ACFI ratings, 2009-2015

Date	30/6/09	30/6/10	30/6/11	30/6/12	30/6/13	30/6/14	30/6/15
Persons	157339	162994	165945	168056	169902	174559	169705
Females	111313	114601	116136	116660	117210	119633	115963
Mean age	84.0	84.1	84.2	84.3	84.4	84.5	84.6
Mean ADL	1.861	1.961	2.066	2.156	2.185	2.234	2.326
Mean BEH	1.868	2.002	2.136	2.235	2.266	2.286	2.373
Mean CHC	1.335	1.492	1.667	1.839	1.946	2.068	2.266
Infectious & parasitic	695	779	853	941	914	971	970
Neoplasms	11261	11466	11625	11694	11354	11128	10283
Diseases of the blood	3419	3232	2884	2623	2372	2260	2001
Endocrine, nutritional	32936	33454	33454	32494	32225	31993	30050
Dementia	81852	84339	86003	87349	87866	90481	88133
Mental & behavioural	69383	76282	81915	86464	90640	95998	97172
Nervous system	22042	22240	22060	22038	21811	21958	21332
Eye & adnexa	23253	23369	23226	22918	22473	22574	21366
Ear & mastoid	8996	9117	8938	8756	8362	8266	7357
Circulatory	92711	92798	90997	87982	84864	83352	77200
Respiratory	17264	17215	17345	17151	16933	16908	16025
Digestive system	15551	14931	14286	13471	12431	11613	10334
Skin & subcutaneous	5603	6064	6410	6607	6452	6305	5735
Musculoskeletal	70872	74862	77694	80459	82551	87102	88006
Genitourinary system	22338	25091	27490	29336	30667	32248	31995
Congenital	587	587	586	525	498	506	468
External causes	12575	13884	14707	15125	15413	15935	15654

Source: AIHW 2016.

Increases in ACFI ratings from 30 June 2009 to 2015

Numeric ADL, BEH and CHC values were derived by taking 0 for '*nil*', 1 for '*low*', 2 for '*medium*' and 3 for '*high*'. Table 1 shows that mean ADL values were 1.861 at 30 June 2009, and 2.326 at 30 June 2015, an increase of 25%. Mean BEH values rose by 27% in the same period, and mean CHC values by 70%. One reason for this trend may be that residential care providers have gradually adopted more liberal interpretations of the ACFI guidelines, and the audit and penalty processes have been inadequate to control this drift. The ACFI system was introduced because the previous classification system suffered from upwards compression (Andrews-Hall, Howe & Robinson 2007). Similar problems have been observed in Ontario (Hirdes & Kehyayan 2014). One of the problems examined in this paper is the derivation of reasonable transition assumptions in the presence of continuing drift.

Healthier residents?

The proportion of residents with life-threatening diseases has reduced over the 6 years to 30 June 2015 as suggested in Table 1. The numbers of residents increased by 8%, but the numbers reported with neoplasms fell by 9%, the numbers with circulatory diseases fell by 17% and the numbers with respiratory diseases fell by 7%. The numbers reported with dementia increased by 8%, in line with the numbers of residents. By contrast, the numbers reported with mental and behavioural problems increased by 40%, those with musculoskeletal problems increased by 24%, and those with genitourinary diseases by 43%. Several hypotheses can be made to explain these implausible divergences:

- Improvements in public health and disease treatment have reduced the numbers of older persons with life-threatening diseases;
- Increased reporting of subsidy-enhancing conditions has left inadequate room for reporting other conditions (the data entry system provides room for only three physical conditions, as well as for three behavioural conditions);
- The increased ability of residential care providers to charge large entry deposits may have created a bias towards more wealthy entrants, with fewer life-threating diseases.

Numbers of ACFI domain transitions July 2014 to May 2014

Table 2 shows the numbers with each domain value at the start of each month from July 2014 to May 2015, and the numbers of these in each possible value at the end of the month. For example, there were 588,314 residents with ADL level 2 at the start of a month, and by the end of the month 4 had dropped to ADL level 0, 531 to level 1, and 18,681 had risen to level 3. Most care residents keep the same level of assistance needs or move one level up after a re-appraisal. Transitions in June 2015 are not shown in Table 2 as no data were available on ACFI assessments at the end of that month. While transitions are in general to higher need levels, there are some to lower needs.

Table 2 Numbers of monthly transitions between the assistance needs levels, 2014-2015

Numbers at start	Numbers at end	Numbers at end	Numbers at end	Numbers at end	Numbers at end
	adl=0	adl=1	adl=2	adl=3	Total
adl=0	23,924	859	281	128	25,192
adl=1	62	341,696	10,210	4,680	356,648
adl=2	4	531	569,098	18,681	588,314
adl=3	2	76	1,064	894,392	895,534
Total	23,992	343,162	580,653	917,881	1,865,686
	beh=0	beh=1	beh=2	beh=3	Total
beh=0	110,451	2,174	1,813	1,150	115,588
beh=1	550	251,700	6,033	6,002	264,285
beh=2	191	1,293	379,874	11,448	392,806
beh=3	79	661	2,604	1089665	1093009
Total	111,271	255,828	390,324	1,108,265	1,865,686
	chc=0	chc=1	chc=2	chc=3	Total
chc=0	94,639	2,130	2,199	1,196	100,164
chc=1	265	356,698	8,144	9,625	374,732
chc=2	107	1,126	527,266	18,335	546,834
chc=3	30	360	1,687	841,880	843,957
Total	95,041	360,314	539,296	871,036	1,865,686

Source: AIHW 2016.

Logistic models of monthly mortality rates

The logistic model coefficients in Table 3 were based on 306,812 deaths in the 6 years to 30 June 2015, and on 53,724 deaths in the 1-year period from 2014 to 2015. The models were fitted by backwards stepwise regression, omitting variables not significant at the 5% level. The first model in the table was based on the 6 years of data, allowing for sex (0 for male, 1 for female), age and year relative to 2014-15 (for example, 2009-2010 was coded as '-5'). Dummy (0,1) variables were included for each ACFI domain level, relative to the lowest possible value for the domain. The second model in Table 3 used the same independent variables as the first, except that only 2014-2015 exposures were considered. Models 3 and 4 did not include the assistance needs variables, and instead used (0,1) codes for the specific ICD diseases reported in ACFI assessments. Models 5 and 6 used both needs and diseases as independent variables. The coefficients are the fitted model values, rather than the exponentiated values sometimes reported as odds ratios.

Table 3. Coefficients of logistic models of mortality rates while in residential aged care

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variable	Needs	Needs	Diseases	Diseases	Needs & diseases	Needs & diseases
Based on:	6 year	1 year	6 year	1 year	6 year	1 year
female	-0.508**	-0.498**	-0.374**	-0.375**	-0.410**	-0.413**
Age	0.034**	0.033**	0.040**	0.040**	0.035**	0.035**
Year	-0.075**		0.011**		-0.066**	
adl1	0.454**	0.426**			0.453**	0.432**
adl2	1.127**	1.091**			1.126**	1.099**
adl3	1.772**	1.846**			1.789**	1.868**
beh1	-0.040**	-0.072				
beh2	-0.145**	-0.168**			-0.083**	-0.089**
beh3	-0.201**	-0.193**			-0.099**	-0.074**
chc1	0.218**	0.124**			0.227**	0.144**
chc2	0.383**	0.253**			0.390**	0.287**
chc3	0.931**	0.691**			0.913**	0.716**
Infectious diseases			0.202**			
head & neck cancer			1.004**	0.990**	0.976**	1.003**
stomach cancer			0.958**	0.981**	0.994**	1.074**
colorectal cancer			0.492**	0.461**	0.515**	0.521**
lung cancer			1.639**	1.523**	1.509**	1.470**
skin cancer			0.186**	0.169**	0.225**	0.277**
breast cancer			0.405**	0.423**	0.413**	0.487**
prostate cancer			0.475**	0.406**	0.462**	0.465**
brain cancer			1.373**	1.331**	1.109**	1.098**
non-Hodgkin's lymphoma			0.662**	0.562**	0.666**	0.644**
leukaemia			0.666**	0.640**	0.738**	0.739**
other malignant tumours			1.207**	1.119**	1.122**	1.105**
other neoplasms			0.549**	0.515**	0.520**	0.551**
anaemia			0.133**	0.150*	0.255**	0.269**
other diseases of blood			0.362**	0.307**	0.450**	0.434**
disorders thyroid gland			-0.018**		-0.057**	
dementia			0.194**	0.195**	-0.018**	
other mental disorders			0.030**	0.052**	-0.090**	-0.085**
nervous system diseases			0.022**		-0.128**	-0.103**
eye & adnexa diseases			-0.181**	-0.195**	-0.078**	-0.097**
ear & mastoid diseases			-0.239**	-0.288**		-0.056**
circulatory system diseases			0.037**	0.040**	0.063**	0.073
upper respiratory infections			0.223**		0.265**	
influenza & pneumonia			0.834**	0.734**	0.694**	0.653**
lower respiratory infections			0.301**	0.278*	0.375**	0.417**
other upper respiratory			-0.085			
chronic lower respiratory			0.312**	0.330**	0.371**	0.416**
other respiratory diseases			0.489**	0.537**	0.563**	0.641**
digestive system diseases			-0.115**	-0.131**	0.028**	
skin & subcutaneous tissue			0.172**	0.195**		0.096**
musculoskeletal & connective			-0.194**	-0.179**	-0.184**	-0.177**
genitourinary system diseases			0.116**	0.093**	0.035**	0.028
external causes				-0.051*	-0.140**	-0.140**
constant	-8.157**	-7.897**	-6.951**	-6.975**	-8.407**	-8.296**
LLR	0.0561	0.0493	0.0260	0.0233	0.0690	0.0611

* Reference categories: Gender (Male); Year (2014-2015); ADL, BEH & CHC (Not having an ADL, BEH & CHC); ICD (Not having an ICD);

** Results significant at the 0.1% level are marked **, 0.1% to 1% *, and 1% to 5% with no mark (all other variables).

As in the population out of residential care, females have lower mortality rates, and mortality rates increase with age. Increasing ADL and CHC levels have higher probabilities of death. Surprisingly, persons with higher BEH levels have slightly lower mortality rates, perhaps because dementia sufferers may need institutional care earlier than would have been necessary based on their physical needs. Some types of cancer considerably increase mortality rates, and some respiratory diseases also have substantial mortality increases. Using both needs and disease variables gives generally similar coefficients. The log-likelihood ratio of the model fitted to needs over the 6 years is 0.056, rising to 0.069 when disease variables are included.

Logistic models of monthly transition rates

Table 4 shows the coefficients of 36 logistic models fitted to data on transitions in July 2014 to May 2015. This short data period was chosen to minimise the effects of the long-term changes that have been occurring in ACFI assessments. The models were initially fitted by backwards stepwise regression, retaining coefficients significant at the 5% level. Where the coefficients fitted to ADL1, ADL2 and ADL3 appeared inconsistent with each other, they were omitted, and new models fitted. Similarly, inconsistent values for BEH1, BEH2 and BEH3, and for CHC1, CHC2 and CHC3 were omitted.

In nearly all cases, the age coefficients for upwards transitions were positive, and the age coefficients for downwards transitions were negative. This strongly suggests that deteriorations occur more often as persons' age, and improvements less often. In general, upwards transitions had positive coefficients for ACFI levels, and downwards transitions had negative coefficients for ACFI levels. For example, the transition from ADL level 1 to level 0 had large negative coefficients for BEH3, CHC2 and CHC3. Exceptions occurred for BEH level 0 to 1, 0 to 2 and 2 to 3, which had negative coefficients for CHC2 and CHC3. Models of CHC transitions had no BEH variables, but were strongly affected by ADL values.

Table 4. Logistic models for monthly transitions between assistance needs

Monthly transition assumptions - ADL								
change	age	beh1	beh2	beh3	chc1	chc2	chc3	constant
0 to 1	0.014**							-4.498**
0 to 2	0.021*							-6.231**
0 to 3	0.052**							-9.921**
1 to 0	-0.050**			-1.136*		-0.947*	-1.273	-3.598**
1 to 2	0.017**	0.242**	0.251**	0.185**				-5.138**
1 to 3	0.038**	0.216**	0.229**	0.466**				-7.808**
2 to 0								-11.899**
2 to 1	-0.030**		-0.345*	-0.782**	-0.388**	-0.582**	-1.094**	-3.352**
2 to 3	0.020**							-5.110**
3 to 0								-11.329**
3 to 1	-0.042**							-5.908**
3 to 2	-0.019**	-0.528**	-0.539**	-1.213**	-0.489	-0.911**	-1.357**	-3.125**

Monthly transition assumptions - BEH								
change	age	adl1	adl2	adl3	chc1	chc2	chc3	constant
0 to 1	0.010**					-0.148*	-0.433**	-4.724**
0 to 2	0.0062	0.326*	0.467**	0.302		-0.128	-0.299**	-4.907**
0 to 3								-4.600**
1 to 0			-0.230	-0.788**		-0.319*	-0.348*	-5.777**
1 to 2	0.010**							-4.582**
1 to 3								-3.762**
2 to 0			-0.468*	-1.211**				-7.105**
2 to 1								-5.713**
2 to 3	0.004**					-0.204**	-0.579**	-3.553**
3 to 0	-0.031**							-6.959**
3 to 1			-0.298*	-1.044**		-0.671**	-1.042**	-6.211**
3 to 2			-0.399**	-1.106**		-0.328**	-0.915**	-4.909**

Monthly transition assumptions - CHC					
change	age	adl1	adl2	adl3	constant
0 to 1	0.012**				-4.853**
0 to 2	0.019**				-5.410**
0 to 3	0.022**	0.293	0.729**	0.917**	-6.730**
1 to 0	-0.024**	-1.124**	-1.791**	-2.445**	-3.757**
1 to 2	0.010**				-4.693**
1 to 3	0.019**	0.492**	0.754**	0.793**	-5.903**
2 to 0	-0.0205	-1.236**	-1.852**	-2.958**	-4.947**
2 to 1	-0.010**	-0.579**	-0.987**	-1.638**	-4.279**
2 to 3	0.013**	0.500**	0.597**	0.471**	-4.994**
3 to 0	-0.040**				-6.902**
3 to 1	-0.012**				-6.725**
3 to 2			-0.632**	-1.581**	-5.123**

* Results significant at the 0.1% level are marked **, 0.1% to 1% *, with all other variables, significant between 1% and 5%.

Life expectancies

A sample of the life expectancy estimates for both sexes and selected combinations of assistance needs is shown in Table 5. Females have longer life expectancies than males with the same assistance needs levels. Life expectancies drop as needs levels rise, and drop with age. For example, a female aged 85 assessed as level 1 in all three domains has an estimated life expectancy of 4.18 years. If she is assessed at level 3 in all domains, her estimated life expectancy is 2.17 years.

Table 5. Sample life expectancy estimates in residential care, by age and assistance needs

Sex	ADL	BEH	CHC	65	75	85	95	105
Male	0	0	0	6.44	5.02	3.88	2.98	2.27
Male	1	1	1	5.37	4.12	3.15	2.39	1.81
Male	2	2	2	4.15	3.17	2.41	1.84	1.40
Male	3	3	3	2.53	1.86	1.36	1.00	0.74
Female	0	0	0	8.17	6.39	4.96	3.82	2.91
Female	1	1	1	7.06	5.45	4.18	3.19	2.42
Female	2	2	2	5.79	4.44	3.40	2.60	1.99
Female	3	3	3	3.99	2.95	2.17	1.60	1.17

* The calculation of the life expectancy follows the equation 4, but with two assumptions. Firstly, those persons who exited but did not re-enter a residential care facility were assumed to be dead, and secondly, the equation ignores the likelihood of simultaneous changes in the domains.

Source: Calculated using AIHW, 2016.

Life expectancy estimates with unit mortality loading

All the original life expectancy calculations in Table 5 were done without simulating the effects of diseases[2]. Because most of the cancers have a coefficient of around 1 (head and neck cancer 1.003; $p < 0.001$, stomach cancer 1.074; $p < 0.001$, brain cancer 1.098; $p < 0.001$, other malignant tumours 1.105; $p < 0.001$), the loading of 1 is added to show the effect of diseases with a coefficient of 1. Table 6 shows life expectancy estimates obtained by adding 1.0 to the logistic mortality score, as percentages of the estimates without loadings in Table 5. For example, head and neck cancer is estimated in Table 3 to add about 1.003 to the logistic mortality score. A female aged 85 with all needs at level 3 and this form of cancer might be estimated to have a life expectancy of about 50% of the 3.4 years in Table 5, or about 1.7 years.

Table 6. Life expectancy estimates with unit mortality loading, as % of no-loading estimates

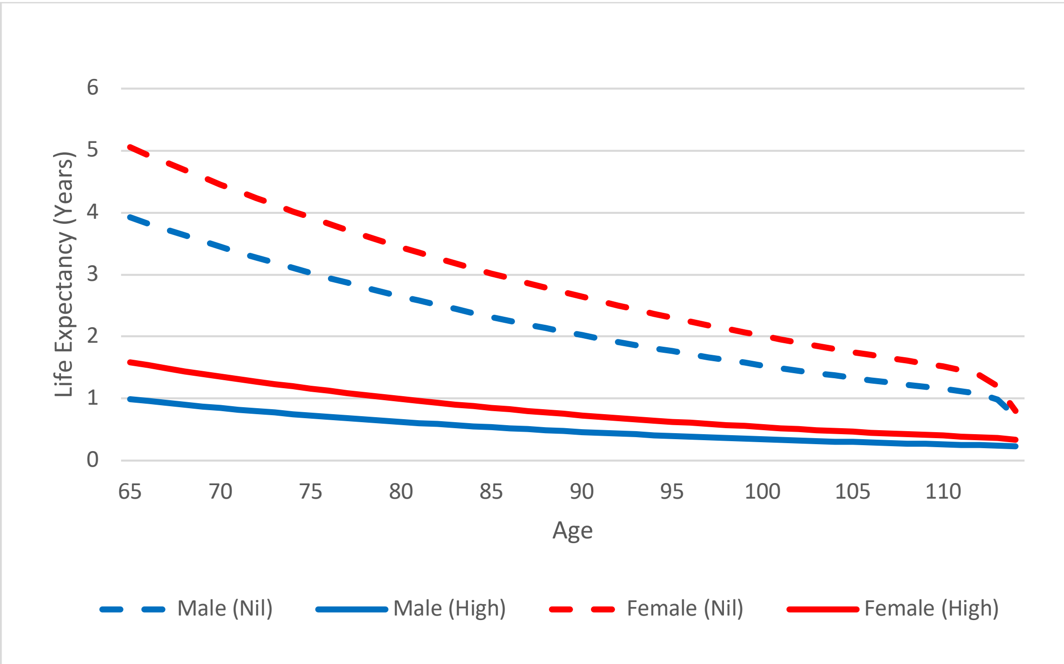
Sex	ADL	BEH	CHC	65	75	85	95	105
Male	0	0	0	61%	60%	60%	59%	59%
Male	1	1	1	56%	56%	55%	55%	55%
Male	2	2	2	49%	49%	49%	48%	48%
Male	3	3	3	39%	39%	39%	40%	41%
Female	0	0	0	62%	61%	61%	60%	60%
Female	1	1	1	57%	57%	56%	56%	56%
Female	2	2	2	51%	50%	50%	49%	49%
Female	3	3	3	40%	39%	39%	39%	40%

Source: Calculated using AIHW, 2016.

[2] In terms of simulation, we can say the loading equals to 0.

Figure 2 shows the life expectancy estimates in residential care by sex and by assistance needs, with the two most extreme cases being compared. The "*Nil*" values are for persons with the lowest possible values for the ADL, BEH and CHC domains (0-0-0), whereas the "*High*" values represent persons with the highest possible values of these domains (3-3-3). Gender differences in life expectancies are obvious, with females expected to live longer than males with the same care needs levels. For example, females aged 80 assessed as having no needs for assistance are expected to live about 3.6 years compared to their male counterparts who are expected to live only about 2.7 years. Because life expectancies drop with age, differences between sexes and between extreme cases of assistance needs become less pronounced. For instance, at age 90, men with the 'High" assistance needs are expected to live only 3-4 months shorter than women with the same age and level of care needs.

Figure 2. Life expectancy estimates by sex and the level of assistance needs



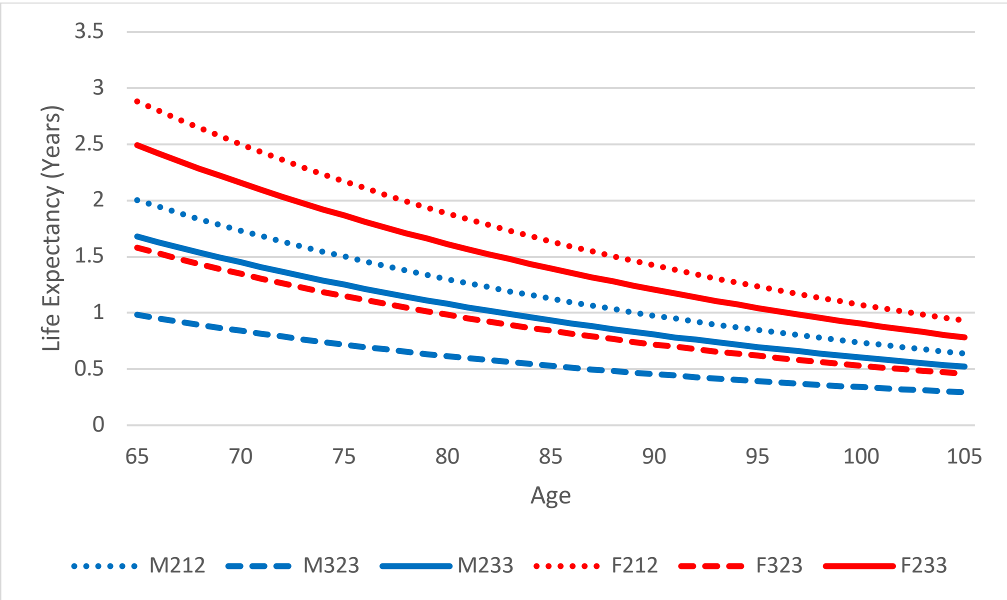
† Life expectancies with included transitions between care assistance needs;
‡ Male/female (Low) refers to male/female with no assistance needs in any domain, whereas male/female (High) is male/female with the highest scores in all three domains (ADL = 3, BEH = 3 & CHC = 3)

Source: Author, October 2016.

Using microsimulation to distribute estimates for months till death

The mortality model in the third column of Table 3, and the transition models in Table 4, were used to make 10,000 random simulations of months till death, for selected cases. These simulations confirmed the estimates in Table 5, and could be valuable in giving individuals probability distributions of how long they are likely to live. Simulated life expectancies for selected levels of assistance needs are shown in Figure 3. Besides already observed differences in life expectancy between genders and change in life expectancy with age, we can observe how certain combination of assistance needs affect the estimated life expectancy. For example, both males and females with the combination of assistance needs '3-2-3' (ADL = 3, BEH = 2 and CHC = 3) are expected to live much shorter than those with the combination '2-3-3' (ADL = 2, BEH = 3 and CHC = 3). This means that having a higher level in the ADL domain, shortens the life expectancy in residential care more than having a higher level in the BEH domain, controlling for the CHC level. In a similar way, it is possible to simulate and compare each combination of care needs.

Figure 3. Simulated life expectancy estimates by sex and selected levels of care needs



† Simulated life expectancies with included transitions between care assistance needs;
‡ Male/female (212) refers to male/female with ADL = 2, BEH = 1, CHC = 2, male/female (323) is male/female with ADL = 3, BEH = 2, CHC = 3; male/female (233) is male/female with ADL = 2, BEH = 3, CHC = 3.

Discussion

This paper has broadened our understanding of the residential aged care system in Australia by providing important evidence about: (1) *Changes in the ACFI system in the period 2008-2015*; (2) *Mortality rates*; (3) *Transition rates between the assistance needs* and (4) *Life* *expectancy in residential care*. These key pieces of evidence are necessary to fully understand the dynamics of functional decline of nursing home residents.

The ACFI system analysis has revealed the effects of aged care policies on system dynamics. For example, a high number of entries to residential care in the period from mid-2013 to mid-2014 is likely a consequence of a new assets and income test applied to persons entering care from 1 July 2014. Furthermore, the continuous upward trend in ACFI appraisals outcomes may be a result of more liberal interpretations of the ACFI guidelines by residential care providers and a lack of consistent audit and penalty processes to control the upward drift in ACFI scores.

Statistical models derived from longitudinal data on 1.05 million ACFI assessments addressed our research questions: (1) *What is the life expectancy for each combination of care assistance needs? and* (2) *How do the residents' assistance needs change in residential care?* Firstly, the model of mortality in residential care was derived (Table 3) showing association between mortality as an outcome, and age, gender, care assistance needs and diseases as predictors. Secondly, models of transitions between assistance needs (Table 4) were derived to show the likelihood of occurrence of each specific transition using demographics and other assistance needs as predictors. Finally, the results of the mortality and transition models were used to give estimates of life expectancy in residential care (Tables 5 & 6).

The results showed that residents' assistance needs are good predictors of the probability of death in residential care and good predictors of the probability of transition towards other levels of care needs. Effects of diseases were also examined and put to the test. Simulation was used to show how adding a specific disease, such as cancer, can halve the life expectancy in residential care. Quantitative insights such as this can be used to test the effects of changes in disease incidence (i.e. scenario testing) on the demand for residential aged care.

The life expectancy and transition estimates may help policy makers to review the current occupancy and waiting times for long-term care and to predict future long-term care needs with better accuracy. These numerical measures can set the foundation for more precise estimates of the costs of residential care. Besides financial aspects, the estimates are relevant for providers of care services. For example, residential care providers could plan their workforce needs if they knew how certain assistance needs will progress with time spent in care and what these changes mean for an individual's life expectancy.

The findings also suggest that the ACFI longitudinal data provide sufficient details to model transitions between assistance needs levels and to estimate life expectancy in residential care. Administrative longitudinal data is free from non-response rates, under-reporting or attrition and, therefore, can be used to fit complex models. Millions of records resulting from each ACFI appraisal give high statistical power and advantage over other techniques in terms of accuracy. However, the data showed continuing changes in reporting practices, making even the most recent data of limited value for projections.

The continuing changes in reporting practices and procedures are of considerable concern to the Australian Government, as they are falsely inflating the subsidy claims by providers of residential aged care. Possible system changes are higher penalties for misreporting, stronger audit procedures or external assessment systems. Although residential care systems differ widely between countries, the techniques in this paper may still be of some value to governments, providers and residents in other countries.

ACKNOWLEDGEMENTS

I am grateful for help provided by Richard Cumpston, Peter McDonald and Jeromey Temple.

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