The effect of dementia trends and treatments on longevity and disability: a simulation model based on the MRC Cognitive Function and Ageing Study (MRC CFAS)*

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Abstract

Background: the numbers with dementia are projected to double between 2001 and 2040, in line with continued increases in life expectancy. Projections have failed to account for the impact of changing risk factors on future numbers with dementia or disability.

Objective: to estimate the size of the disabled population over the next 20 years and explore the impact of treatments that delay onset of cognitive impairment and associated disability.

Methods: a dynamic macro-simulation projection model was used to calculate the numbers of older people with disability to 2026. Transition rates to disability and death conditional on a range of conditions, calculated from the MRC Cognitive Function and Ageing Study, were applied to the 1992 England and Wales population. Scenarios for trends in dementia incidence, risk factors and treatment were devised from a systematic review and applied.

Findings: population ageing alone resulted in 39% more older people between 2006 and 2026 and 82% more with disability. A combination of reduced incidence of cognitive impairment and disabling consequences alongside improved survival provided the largest reductions in the disabled population (15,000) and the numbers cognitively impaired (302,000) compared with ageing of the population alone.

Interpretation: population ageing alone will increase the disabled older population by over 80% and the numbers cognitively impaired by almost 50% over the next 20 years with serious implications for the provision of care. Research priorities should focus on earlier detection of dementia and its risk factors, thereby allowing earlier and more targeted treatment to alleviate its associated disability.

Keywords: dementia, epidemiology, disability, mortality, elderly

Life expectancy at birth is increasing by 3 years every decade, and by 2020 one in five people in the United Kingdom (UK) will be over 65 years of age. Strongly age-related conditions such as dementia will consequently become more prevalent; it has been estimated that the number of people with dementia worldwide will rise from 24.3 million currently to 42.3 million by 2020 and 81.1 million by 2040. Developed societies such as the UK start from a higher prevalence, and the numbers of
people with dementia are projected to double between 2001 and 2040 [1].

Dementia is a major cause of later life disability [2], and cognitive impairment is present in over a third of disabled people aged 65+ [3]. This has serious consequences not only for individuals and families but also for demands on and costs of health and social care [4–6]. It is important in planning for the needs of older people to have projections based on reliable estimates of the prevalence and incidence of cognitive impairment and its associated disability.

Most projections of numbers with dementia have been based on population demography and epidemiological estimates of prevalence. Two US models have examined the impact of delaying disease onset [7] and the effect of hypothetical new interventions [8] but only in Alzheimer’s disease (AD) and with no consideration of changing risk factors or the impact of existing treatments. Other simulation models exist, but have only considered consequences of changing risk factors or treatments on population mortality [9, 10]. No models have studied the full spectrum of dementia, or considered disability as a major consequence of declining cognitive function.

This paper reports projections of future numbers of older people with disability in England and Wales over the next 20 years. In addition to a base case of population ageing alone, four evidence-based dementia scenarios are explored: (i) reductions in incidence, (ii) improved survival, (iii) reduced disability and (iv) a combination of (i)–(iii). These projections were produced using a dynamic macro-simulation (cell-based) model first developed for the Wanless Social Care Review [11].

Methods

Overview of the model

The initial population for the model was the 1992 mid-year England and Wales revised population estimates from the Office for National Statistics (ONS) for those aged 65 years and over by 2-year age band. Two-year age band and sex-specific disability rates were applied to estimate initial disabled and non-disabled sub-populations. Estimated transition probabilities between non-disabled and disabled states, as well as to death were then applied to produce disabled and non-disabled sub-populations aged 67 years and over, 2 years later. The 65–66-year age group was replenished as follows: from the 1991 ONS population figures (for 1992–2000); from the Government Actuary Department’s (GAD) 2000-based principal projections (2001–2005) and from the GAD 2006-based principal projections (2006–2026). As evidence is equivocal for increased or decreased disability prevalence in newer cohorts [12], we assumed the same prevalence of disability for the incoming cohort throughout. We adjusted both sets of transitions (from disability and disability-free) to death for every 2-year period based on GAD assumptions that death rates will fall. These adjustments may be considered to encompass the impact of diseases not considered in the model. This process was run iteratively to simulate the future disabled population from 1992 to 2026.

Data

Initial prevalence of disability and transition probabilities between disability and death for dementia and other diseases were estimated from the MRC Cognitive Function and Ageing Study (MRC CFAS) [13], a nationally representative longitudinal study of 13,004 community-dwelling and institutionalised residents aged 65 years and over. Disability was defined as participants’ inability to put on shoes and socks, have a bath or all-over wash, or inability to transfer to and from bed; this level of severity was chosen to reflect the need for social care [11]. Transition probabilities from disability-free to disability and death at 2 years conditional on disease patterns were estimated from a trichotomous logistic regression model in 8,693 participants disability-free at baseline [14]. Prevalent chronic conditions included were cognitive impairment, coronary heart and peripheral vascular disease, diabetes, asthma, chronic bronchitis, arthritis, Parkinson’s disease, treated hypertension and stroke. Cognitive impairment was assessed by the Mini-Mental State Examination (MMSE) [15], with mild cognitive impairment defined by scores of 22–25 and moderate and severe scores of 21 or less, the latter reflecting a high probability of dementia [16, 17]. Transition probabilities from disability to recovery and death were estimated from smoothing the observed age-specific rates by linear regression models. Further details of the model are presented in Appendix 1 (available online).
The effect of dementia trends and treatments on longevity and disability

Table 1. Total population and numbers with disability, and with cognitive impairment (thousands) by age from the dynamic macro-simulation model base case, percentage in parentheses

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Population</th>
<th>With Disability (%)</th>
<th>With Mild Cognitive Impairment (%)</th>
<th>With Moderate + Cognitive Impairment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
<td>2012</td>
<td>2016</td>
<td>2022</td>
</tr>
<tr>
<td>65–74 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>4,454</td>
<td>5,108</td>
<td>5,630</td>
<td>5,717</td>
</tr>
<tr>
<td>With disability (%)</td>
<td>209 (4.7)</td>
<td>253 (5)</td>
<td>289 (5.1)</td>
<td>303 (5.3)</td>
</tr>
<tr>
<td>With mild cognitive impairment (%)</td>
<td>551 (12.4)</td>
<td>628 (12.3)</td>
<td>697 (12.4)</td>
<td>716 (12.5)</td>
</tr>
<tr>
<td>With moderate + cognitive impairment (%)</td>
<td>133 (3)</td>
<td>154 (3)</td>
<td>174 (3.1)</td>
<td>181 (3.2)</td>
</tr>
<tr>
<td>75–84 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>3,180</td>
<td>3,238</td>
<td>3,377</td>
<td>4,008</td>
</tr>
<tr>
<td>With disability (%)</td>
<td>326 (10.3)</td>
<td>369 (11.4)</td>
<td>406 (12)</td>
<td>492 (12.3)</td>
</tr>
<tr>
<td>With mild cognitive impairment (%)</td>
<td>775 (24.4)</td>
<td>789 (24.4)</td>
<td>822 (24.4)</td>
<td>969 (24.2)</td>
</tr>
<tr>
<td>With moderate + cognitive impairment (%)</td>
<td>297 (9.3)</td>
<td>316 (9.7)</td>
<td>336 (10)</td>
<td>397 (9.9)</td>
</tr>
<tr>
<td>85+ years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>1,221</td>
<td>1,393</td>
<td>1,490</td>
<td>1,737</td>
</tr>
<tr>
<td>With disability (%)</td>
<td>320 (26.2)</td>
<td>399 (28.6)</td>
<td>450 (30.2)</td>
<td>569 (32.8)</td>
</tr>
<tr>
<td>With mild cognitive impairment (%)</td>
<td>347 (28.4)</td>
<td>391 (28.1)</td>
<td>414 (27.8)</td>
<td>477 (27.4)</td>
</tr>
<tr>
<td>With moderate + cognitive impairment (%)</td>
<td>382 (31.3)</td>
<td>450 (32.3)</td>
<td>492 (33)</td>
<td>593 (34.1)</td>
</tr>
<tr>
<td>All 65+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>8,855</td>
<td>9,740</td>
<td>10,497</td>
<td>11,463</td>
</tr>
<tr>
<td>With disability (%)</td>
<td>855 (9.7)</td>
<td>1,021 (10.5)</td>
<td>1,145 (10.9)</td>
<td>1,564 (11.9)</td>
</tr>
<tr>
<td>With mild cognitive impairment (%)</td>
<td>1,673 (18.9)</td>
<td>1,808 (18.6)</td>
<td>1,934 (18.4)</td>
<td>2,162 (18.9)</td>
</tr>
<tr>
<td>With moderate + cognitive impairment (%)</td>
<td>812 (9.2)</td>
<td>920 (9.4)</td>
<td>1,002 (9.5)</td>
<td>1,171 (10.2)</td>
</tr>
</tbody>
</table>

aAssumption of no change in age-specific prevalence of disease, incidence and recovery rates to disability, and mortality rates continuing to decline at levels commensurate with GAD principal projections.

data on the impact on disability, except that cholinesterase inhibitors (CEIs) may reduce disease-specific disability [19].

Given the paucity of data on the impact of interventions on disability, we assumed a change of 5% in either the transition probabilities to onset of disability or to death to represent a small impact, and 10% a moderate one. The main scenarios were built around assumptions of future reductions in incidence, improvements in survival with dementia and reductions in disability consequent to dementia through new and existing treatments as follows:

- **Reduced incidence** of dementia of 10% from 2012, to reflect assumptions of delayed onset [7] or better control of hypertension [20], estimated by reducing dementia prevalence by 2% cumulatively every 2 years from 2012 for mild cognitive impairment and from 2016 for moderate or severe.

- **Improved survival** with dementia consequent upon control of vascular risk factors in those with mild cognitive impairment. As mortality already reduces commensurate with GAD projections, we assume only a small further reduction of 5% in those with mild dementia from 2012.

- **Reduced disability** with dementia in line with evidence that CEIs could delay the time to functional decline by 6 months to 1 year [19, 21]. CEIs are presently recommended only for patients with a MMSE score 10–20 (http://www.nice.org.uk), and this was included in the model as a 10% reduction in transitions to disability for moderate or worse cognitive impairment only, although observational evidence of efficacy in patients with mild cognitive impairment exists [22]. However, uptake of CEIs in those who might potentially benefit is low [23]. To explore the effect of greater uptake, we assumed a 5% reduction in the transitions to disability from 2010 in mild and a 10% reduction in moderate or severe cognitive impairment.

- **Combined scenario** in keeping with optimal control of vascular risk factors [24, 25].

**Results**

Disability prevalence in 1992 ranged from 3.7% at 65–66 years to 58.7% at 91 years and over. The baseline prevalence of mild cognitive impairment was 24.2% and of moderate or worse 13.2%. The simulation model predicts that population ageing alone would result in a 39% increase in the population aged 65+ between 2006 and 2026 (8.9–12.3 million), with those aged 85+ increasing by 61% (Table 1). Over the same period, this results in an 82% increase in numbers of disabled older people (0.9–1.6 million).

**Total numbers aged 65+**

Compared to population ageing alone, further increases in the size of the population aged 65+ would result from all scenarios considered (Figure 1), including reduced dementia incidence, since mortality is lower in those without cognitive impairment. The combined scenario produces the largest population increase between 2006 and 2026 (118,000), whilst reduction of the disabling consequences of dementia leads to the smallest (12,000).
Numbers with disability

Decreases in the disabled older population result from all but one of the scenarios (Figure 1). The combined scenario produces the greatest decrease (15,000) from population ageing by 2026. In contrast, increasing survival of those with dementia leads to an increase in the disabled population of 4,400. Widening use of CEIs by those with mild dementia has a small effect, with 5,000 fewer having disability by 2026.

Numbers with cognitive impairment

Population ageing alone results in a 48% increase between 2006 and 2026 in the numbers of older people with cognitive impairment of all severities, from 2.5 million to 3.7 million (Table 1). Scenarios of improved survival and reductions in dementia-associated disability suggest a similar increase (Figure 2). However, reductions in disease incidence (and the combined scenario) result in smaller (37%) increases than population ageing alone and around 300,000 fewer cases of cognitive impairment by 2026.

Discussion

This dynamic macro-simulation model shows that population ageing alone will result in a 39% increase in the numbers aged 65+ over the next 20 years, with 500,000 more older people with moderate and severe cognitive impairment and over 700,000 more with disability. The largest contribution will be in the population aged 85+ whose numbers will increase by 60%.

The greatest reduction in the disabled population, amounting to 15,000, was from delayed onset, reduced disability and improved survival, achievable through optimal control of vascular risk factors. However, this represents only a 1% reduction in the size of the disabled population. Offsetting the impact of an ageing population will require larger prevention and treatment effects than are currently achievable; our model suggests that halving dementia-related disability will reduce the numbers disabled by 10%.

Systematic reviews of CEIs suggest modest effects on reducing the disabling consequences of dementia [19]. Debate persists on guidance restricting their use to moderate and severe cognitive impairment as many clinicians consider them beneficial for mild dementia [22], although objective
Our scenario of reduced incidence by delayed progression from mild to moderate/severe cognitive impairment reduced the numbers of older people with dementia relative to population ageing alone. However, delaying progression would still produce an overall gain of 37% in the numbers with dementia and mild cognitive impairment of 26% between 2006 and 2026. Another model showed an overall reduction of 10% in numbers with moderate/severe Alzheimer’s disease (AD) but a 47% increase in mild over the same period through delayed onset and slower progression [8], although mortality rates were not based on observed data and transition rates from mild to moderate/severe dementia were assumed to decrease by more than half.

The baseline scenario (population ageing only) gives a 63% increase in numbers with moderate/severe cognitive impairment and a 48% increase in all cognitive impairment over the period 2006–2026. This is close to the 43% increase in numbers aged 60+ with dementia between 2001 and 2020, estimated for Western Europe from a Delphi consensus [1]. In the United States, a reduction in numbers with severe cognitive impairment has been observed, in line with similar declines in disability linked to vascular and mixed dementias [26] and partly accounted for by improved education and wealth [27]. These declines were maintained till 2004 and appear to result from improving health and better management of vascular risk factors [28]. Similar declines in disability prevalence have not been apparent in the UK [12] and there is evidence that management of vascular disease is less than optimal, notably provision of statin therapy [29].

Limitations of our model concern the underlying data. MRC CFAS was a nationally representative longitudinal study of people aged 65+ in 1992 from urban and rural areas and included those living in institutions. Few people from ethnic minorities contributed, and over the next 20 years, these will form an increasing part of the older population. In the 2001 Census, fewer than 3% of the older population were non-whites, compared with 9% for the 40–44-year-old age group. We did not model the impact of ageing on ethnic minority populations because of a lack of data on disability transitions. Nevertheless, the known greater prevalence of stroke, CHD and diabetes in the South Asian population, the largest ethnic minority in the UK, suggests that our estimates may be conservative.

Most projection models have concentrated on one disease and its evolution. Although we have concentrated on scenarios around dementia, our model incorporates different diseases with their varied impacts on disability and mortality. One limitation is that the diseases considered in the transition model were ascertained from self-report. However, most were self-reports of doctor-diagnosed morbidity, and the prevalence of diseases in MRC CFAS is commensurate with other British studies, such as the British Women’s Heart and Health Study [30] and the HSE [18]. Where differences were found we calibrated the model so that estimates for 2006 would reflect the 2005 HSE values. Choice of diseases for the transition model was limited by the study. Cancer notably was omitted; however, this has consistently been shown to have little impact on population disability [31], and limited allowance is made for mortality reductions from this (and other diseases not included) by the GAD adjustments.

The approach of this paper has been to consider some general markers of disability, well validated for use in population settings and shown to measure the general impact of dementia and cognitive impairment on health status [14]. It should be noted that these reflect many other disease determinants of disability, and are not exclusive to cognitive impairment; however, our estimations relate to the overall resulting effects of dementia and cognitive impairment on these disability measures.

Our findings that continued mortality reductions at older ages will result in more disability, and potentially greater healthcare costs, confirm others [32, 33]. Additionally, projection models of future numbers with dementia [7] implicitly echo our findings that population ageing will result in substantial rises in the numbers with cognitive impairment who need care, although primary prevention and optimal treatment could offset a small proportion.

Conclusions

Planning health and social care for older people requires accurate projections of future need based on reliable estimates of disease burden, aetiology and progression. Projection models linking multiple diseases and disability in the manner explored here provide evidence of potential treatment and prevention strategies to reduce future disability burden. Our model confirms that population ageing will result in an 82% increase in numbers disabled over the next 20 years. Research should focus on earlier detection of dementia and its risk factors to allow earlier, more targeted interventions to alleviate disability rather than on treatments that merely prolong life.

Key points

- Ageing of the population alone will result in 82% more disabled older people in the next 20 years and 63% more with moderate or severe cognitive impairment.
- Delaying the onset of cognitive impairment and reducing its disabling consequences could reduce future numbers with disability but these are small with current therapies, offsetting only ~1% of the increase.

Acknowledgements

We are grateful for the cooperation of the then Family Health Service Authorities (a function now embraced by Primary Care Trusts) and local general practitioners and their
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Received 5 August 2008; accepted in revised form 30 January 2009