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RESEARCH PAPER

Projections of dependency and associated social care expenditure for the older population in England to 2038: effect of varying disability progression

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Abstract

Objectives: to assess the effect of recent stalling of life expectancy and various scenarios for disability progression on projections of social care expenditure between 2018 and 2038, and the likelihood of reaching the Ageing Society Grand Challenge mission of five extra healthy, independent years at birth.
Design: two linked projections models: the Population Ageing and Care Simulation (PACSim) model and the Care Policy and Evaluation Centre long-term care projections model, updated to include 2018-based population projections.
Population: PACSim: about 303,589 individuals aged 35 years and over (a 1% random sample of the England population in 2014) created from three nationally representative longitudinal ageing studies.
Main outcome measures: Total social care expenditure (public and private) for older people, and men and women's independent life expectancy at age 65 (IndLE65) under five scenarios of changing disability progression and recovery with and without lower life expectancy.
Results: between 2018 and 2038, total care expenditure was projected to increase by 94.1%–1.25% of GDP; men's IndLE65 increasing by 14.7% (range 11.3–16.5%), exceeding the 8% equivalent of the increase in five healthy, independent years at birth, although women's IndLE65 increased by only 4.7% (range 3.2–5.8%). A 10% reduction in disability progression and increase in recovery resulted in the lowest increase in total care expenditure and increases in both men's and women's IndLE65 exceeding 8%.
Conclusions: interventions that slow down disability progression, and improve recovery, could significantly reduce social care expenditure and meet government targets for increases in healthy, independent years.

Keywords: disability, population projections, social care, dependency, life expectancy, older people

Key Points

- Previous projections of older people's care needs and social care expenditure have not accounted for recent stalling of life expectancy, or the effect of different trends in disability progression
- Between 2018 and 2038, we project total expenditure on social care services will increase by 94.1–1.25% of GDP, assuming constant 2018 prices
- Men's independent life expectancy at age 65 will increase between 2018 and 2038 by 14.7% (range 11.3–16.5%), but women's will increase by only 4.7% (range 3.2–5.8%).

- Interventions that slow down disability progression, and improve recovery, could significantly reduce social care expenditure and meet government targets for increases in healthy, independent years
- Higher rates of disability progression and lower life expectancy would result in the largest increase in social care expenditure and a reduction in women's independent life expectancy

Introduction

Countries around the world are facing a rapid increase in the demand for, and expenditure on social care for older people [1], coinciding with constraints on public expenditure following the global financial crisis of 2008 onward, and the financial challenges in the years following the Covid-19 pandemic. Projections of future demand for care are valuable to inform planning of budgets and commissioning of services, and to contribute to the development of policy on the funding of social care. It is also crucial to understand, through projections of demand for care and associated costs, the expected effect of policies for improving population health, such as the World Health Organisation's Decade of Healthy Ageing and the United Kingdom's government's Ageing Society Grand Challenge [2, 3].

The demand for, and the costs of, social care depend on several factors, including trends in disability. Few countries worldwide have experienced the ideal of a disability compression, where trends in disability-free life expectancy increase at a faster rate than trends in overall life expectancy [4]. Lack of consistency in disability measurement impedes global comparisons, but analysis of trends in Healthy Life Years (HLY) between 2008 and 2016, across the (then) 28 countries of the European Union, suggests that only four countries (Slovakia, Germany, Ireland, Hungary) experienced compression of disability, whereas six countries, including the UK, experienced a period of disability expansion, with life expectancy increasing faster than HLY [5]. The aim of this paper is to present the updated estimates of the numbers requiring care and associated care expenditure for older people in England to 2038, using the 2018-based population projections with varying assumptions of disability progression, and to assess which scenarios for disability progression are likely to meet the UK government's Ageing Society Grand Challenge of increasing healthy, independent life years at birth by 5 years by 2035 [3].

Methods

We used two linked projections models developed in previous studies: the Population Ageing and Care Simulation (PACSim) model and the Care Policy and Evaluation Centre (CPEC) long-term care projections model. Full details of the models and their assumptions have already been published [6–8] but brief details of each are provided here.

PACSim is a discrete time dynamic microsimulation model that simulates characteristics (sociodemographic, health behaviours, chronic diseases, geriatric conditions and dependency) of individuals aged 35 and over from three longitudinal studies: Understanding Society, the English Longitudinal Study of Ageing and the Cognitive Function and Ageing Study II, re-weighted to the population of England in 2014 [6]. The base population comprised a 1% sample of the England population aged 35 years and over (n = 303,588). Dependency was measured by the 'interval of need' (IoN) [9], which categorises individuals according to the frequency with which they need care: high dependency (needs 24-h care), medium dependency (needs help at regular times daily), low dependency (needs help less than daily), independent (free from care). Further details of the IoN classification are available [10]. Transition probabilities for each stochastic characteristic were calculated from generalised linear models fitted to the baseline and subsequent follow-up of the pooled studies (see [10] for full details), to enable projections of dependency to reflect simulated trends in health behaviours, chronic diseases and mortality and their interrelationships. We updated the survival probabilities for each individual in the original PACSim model to the 2018-based projections [11]. Estimated life expectancy at age 65 between 2018 and 2041 from PACSim was within 2% for men and 2.5% for women compared with the estimates from the Office for National Statistics [12].

PACSim produces projections of the time spent requiring different levels of care at age 65 using Sullivan's method [13], i.e. by applying the age-sex-specific prevalence of each level of care need to the age-sex-specific lifetable population generated from the survival probabilities. To assess changes in independent life expectancy at age 65(IndLE65) against this, we converted the UK government's Ageing Society Grand Challenge mission of an increase of 5 years at birth [3] to a percentage increase. The latest estimates of disability free life expectancy (DFLE) at birth for England (2017–19) are 62.7 years for men and 61.2 years for women [14], and an increase of five healthy years corresponds to an 8% increase for men and women. We therefore assessed whether the percentage increase in IndLE65 between 2018 and 2038 from PACSim exceeded 8%, approximating the 2035 endpoint for the challenge.

Estimates of the projections of the numbers of older people requiring care and the time spent requiring care at different levels are from a single run of PACSim over the time period 2018–2038, but the range of values over 10 simulations is provided as an estimate of uncertainty around these outcomes. Projections of the prevalence of dependency by IoN category, separately by age group, gender and years of education, from PACSim form inputs to the CPEC long-term care projections model.

The *CPEC long-term care projections model,* a cell-based model, makes projections of five key variables: the future numbers of disabled older people; the likely level of demand for unpaid care; long-term care services and disability benefits; the public and private costs associated with meeting this demand; and the social care workforce required. It draws on a number of data sources including Office for National Statistics (ONS) 2018-based population projections, Health Survey for England data for 2015–2017 and National Health Service (NHS) Digital data on numbers of local authority funded older users of adult social care and expenditure on social care for older people in 2018/2019. More information about the model is available [7]. It is important to stress that our projections should not be treated as forecasts. They are based on assumptions about trends in factors that drive demand for care: trends in mortality, disability, household composition (especially living alone), socioeconomic variables (education and housing tenure). The base case assumptions of the projection model are provided in the Appendix.

Long-term care needs are measured in the CPEC model by functional disabilities in performing activities of daily living (ADLs) and instrumental activities of daily living (IADLs). In comparison to IoN, which focuses on the frequency of needing help, this measure focuses on the number of tasks with which people need help. The proportions of older people with different levels of IoN by age and gender in PACSim were matched with those with ADL or IADL disabilities in the CPEC model so that the future trends in IoN projected by PACSim could be mapped into trends in functional disabilities, which fed into the CPEC model. The outputs from 10 simulations of the PACSim model (see above) were run through the CPEC model, leading to a range of results capturing the uncertainty around projected number of care users and care expenditure.

Scenarios for disability progression

We examined the effect on key variables of a set of scenarios exploring transitions to different levels of dependency, implemented in PACSim as follows:

- Scenario A: reductions in transitions from independent to mild dependency;
- Scenario B: reductions in transitions from mild to moderate dependency and increases in transitions from mild dependency to independence;
- Scenario C: reductions in all worsening transitions (independent to mild, mild to moderate, moderate to high) and increases in recovering transitions (mild to independent, moderate to mild) (we assume recovery from high dependency to moderate dependency is negligible);
- Scenario D: the opposite of scenario C (increases in all worsening transitions, reductions in all recovery transitions);
- Scenario E: Scenario D with mortality rates as per the low LE variant.

For scenarios A and B we examined changes in transition probabilities of 10% and 20% per year, that is decreases of 10% and 20% to more severe states and increases of 10% and 20% to less severe states; for scenario C and the 'pessimistic' scenarios D and E we examined changes of 10% only. We assumed the reductions/increases began in 2020 and in those age ≥ 65 years only. Two studies examining the effect of obesity and physical activity on the risk of disability informed the magnitude of change in transition probabilities of 10% and 20% per year [15, 16], though it should be noted that other interventions might have greater or lesser effects on transition probabilities. Only one study to date has sufficient detail on changes in transitions to and from disability over time. It found reductions in incidence and improvements in recovery of 10–20% over the period of 1991–2011 which equates to −2% per year, much smaller than those suggested by interventions [17].

Results

Impact of stalling life expectancy in England on levels and costs of care need

Compared with the original PACSim estimates using 2014-based projections, those using 2018-based resulted in fewer older people overall and at all dependency levels (Appendix Table 1). From these, the CPEC model projected increases in: the number of older people unable to perform one or more ADLs without help by 19.3% over the 20-year period (from 1.7 million in 2018 to 2.0 million in 2038), the number of users of community-based care by 44.9% and the number of older people living in care homes by 47.8% (Table 1). These projected increases in numbers carry through to projected increases in public expenditure on social care services of 84.2%, private expenditure on social care by 108.4% and total expenditure by 94.1% (from 0.87% of Gross Domestic Product (GDP) in 2018 to 1.25% of GDP in 2038), at constant 2018 prices (Table 1).

Projections of life expectancy at age 65 from PACSim suggest increases for men of 2.0 years (range from 10 simulations 1.2–2.2 years) and for women of 1.2 years (range 0.9–1.6 years) between 2018 and 2038 (Table 2). Over the same period, IndLE65 would increase by 1.9 years (range 1.5–2.1 years) for men and 0.5 years (range 0.4–0.6 years) for women, corresponding to percentage increases of 14.7% (range 11.3–16.5%) for men and 4.7% (range 3.2–5.8%) for women. Thus, independent life expectancy increases for men are likely to exceed the age 65 equivalent of the Ageing Society Grand Challenge (8%), but this is not true for women.

Effect of improving or worsening transitions to dependency

Of the five main scenarios for changing transitions to dependency considered, Scenario C resulted in the greatest reductions from the base case in numbers with all levels of dependency (2028: Appendix Figure 1; 2038: Appendix Figure 2), and in the number of people with

Table 1. Projected number of older people with ADL limitations and number receiving community and residential care (thousand persons), and projected expenditure on social care (£billion, 2018 prices) in England, 2018–2038, principal population projection

	2018	2023	2028	2033	2038
Social care needs (Thousand persons)					
ADL disabled older people	1,693	1,709	1,775	1,877	2,019
Range[a]	N.A.[b]	(1,673–1,718)	(1,725–1,786)	(1,822–1,879)	(1,979–2,031)
Social care recipients (Thousand persons)					
Community care recipients	346	363	399	450	501
Range	N.A.	(360–365)	(393–401)	(446–453)	(498–504)
Residential care recipients	318	351	374	420	470
Range	N.A.	(338–351)	(351–375)	(396–420)	(450–479)
Total	664	714	773	870	971
Range	N.A.	(699–716)	(744–776)	(841–873)	(948–980)
Expenditure on social care[c] (£billion, 2018 prices)					
Social care net expenditure	8.4	9.9	11.3	13.0	15.4
Range	N.A.	(9.7–9.9)	(11.0–11.3)	(12.7–13.0)	(15.1–15.5)
User charges	2.1	2.5	2.9	3.2	3.8
Range	N.A.	(2.4–2.5)	(2.8–2.9)	(3.1–3.2)	(3.7–3.8)
Private expenditure	7.8	9.6	10.9	13.7	16.3
Range	N.A.	(9.4–9.7)	(10.5–11.1)	(12.9–13.7)	(15.7–16.6)
Total expenditure	18.3	22.0	25.1	29.9	35.5
Range	N.A.	(21.4–22.1)	(24.0–25.1)	(28.7–29.9)	(34.5–36.0)
Total expenditure as % GDP	0.87%	0.98%	1.02%	1.14%	1.25%
Range	N.A.	(0.96–0.98%)	(0.99–1.03%)	(1.09–1.14%)	(1.21–1.26%)

[a]Estimate and range from 10 simulations. [b]Number of publicly funded care users and care expenditure in the base year of 2018 are aligned with the official figures, so there are no range estimates. [c]Expenditure figures relate to local authority net current expenditure and do not include expenditure met by income from user charges or NHS expenditure.

Table 2. Life expectancy at age 65 with each level of dependency, and total life expectancy 2018–2038 for men and women (PACSim 2018-based principal projection and range from 10 simulations)

	Life expectancy	2018	range	2028	range	2038	range
Men	Independent	13.0	(12.8–13.3)	14.2	(14.1–14.4)	14.9	(14.6–15.0)
	Low dependency	3.4	(3.4–3.7)	3.7	(3.7–3.9)	4.2	(4.1–4.3)
	Medium dependency	1.0	(1.0–1.1)	0.7	(0.6–0.7)	0.6	(0.6–0.6)
	High dependency	1.3	(1.2–1.4)	1.0	(1.0–1.0)	0.9	(0.8–0.9)
	Total	18.6	(18.4–19.4)	19.6	(19.5–19.9)	20.6	(20.1–20.8)
Women	Independent	11.1	(10.9–11.1)	11.3	(11.3–11.5)	11.6	(11.5–11.6)
	Low dependency	6.9	(6.7–6.9)	6.9	(6.9–7.1)	7.5	(7.2–7.6)
	Medium dependency	1.2	(1.2–1.3)	1.1	(1.1–1.2)	1.1	(1.0–1.1)
	High dependency	2.0	(1.8–2.0)	2.1	(2.1–2.2)	2.3	(2.2–2.3)
	Total	21.2	(20.8–21.2)	21.4	(21.4–21.9)	22.5	(22.0–22.6)

ADL limitations (Appendix Table 2). Compared with the optimistic Scenarios (A, B, C), Scenarios D and E resulted in fewer older people independent and more with all levels of dependency (2028: Appendix Figure 3; 2038: Appendix Figure 4). Furthermore, the added assumption of lower LE Scenario E produced 82,000 fewer independent older people by 2038 than Scenario D, but also fewer at other levels of dependency (2028: Appendix Figure 3; 2038: Appendix Figure 4) and with ADL limitations (2028: Appendix Figure 5; 2038: Appendix Figure 6).

Scenario C had the lowest number of care recipients and subsequently the lowest expenditure on social care. The numbers of community care recipients and care home residents are projected to increase to 378,000 and 360,000, respectively, in 2028 (Appendix Figure 7), and to 472,000 and 446,000, respectively, in 2038 (Figure 1), with total expenditure on social care increasing to £24.2 billion (0.99% of GDP) in 2028 (Appendix Figure 8) and to £33.8 billion (1.19% of GDP) in 2038 (Figure 2). Scenario E had the highest projected number of care recipients among the five scenarios, with total expenditure on social care projected to rise to £37.0 billion (1.30% of GDP) in 2038. The numbers underlying the figures are provided in Appendix Tables 2 and 3.

All the scenarios, even the 'pessimistic' ones, achieved the 8% increase in IndLE65 target for men; for women, all the

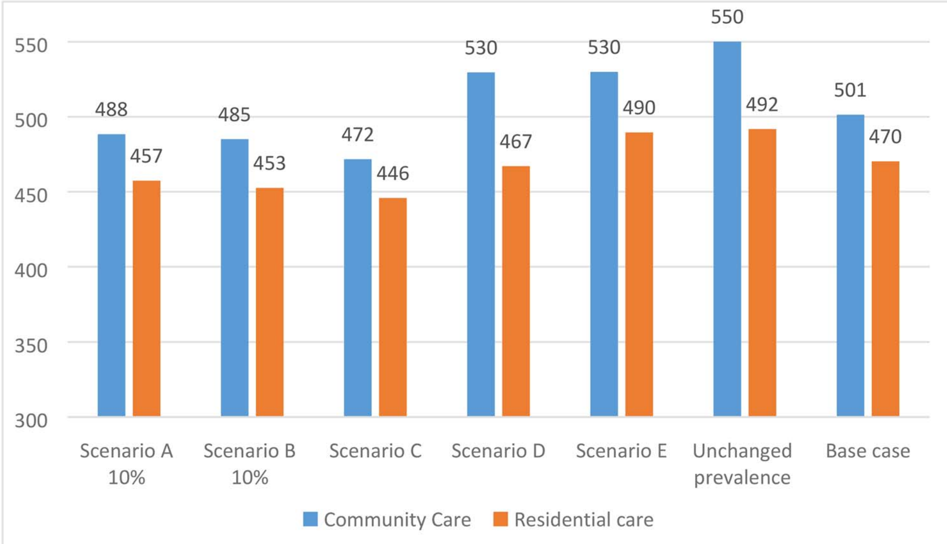

Figure 1. Projected number of older people receiving community care or living in care homes in 2038 for different scenarios of change in transitions (thousand persons).

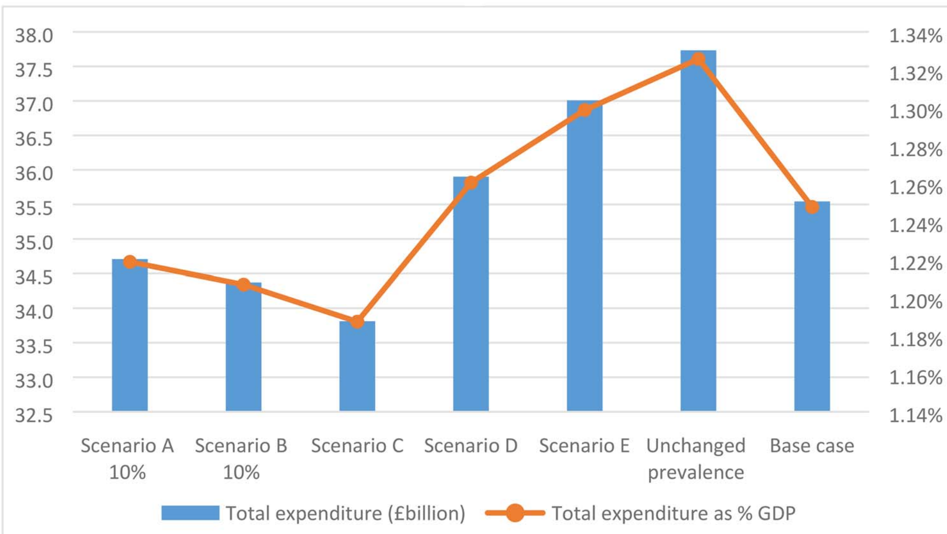

Figure 2. Projected expenditure on social care for older people in England in 2038 for different scenarios of change in transitions (£billion, 2018 prices).

'optimistic' scenarios except Scenario B 10% met the target, but the pessimistic scenarios (Scenarios D and E) resulted in reductions in IndLE65 (Figure 3). The projected years spent from age 65 at each level of dependency in 2018, 2028 and 2038 under each scenario are shown in Appendix Tables 4 (men) and 5 (women).

Discussion

Our findings update projections of older people's care needs and social care expenditure, incorporating the stalling of life expectancy inherent in the 2018-based population projections, and the effect of scenarios to slow down (or increase) disability progression. Our base case projections suggest that, for England between 2018 and 2038, the number of older people with ADL limitations will increase by 19.3%, users of community-based care by 44.9% and older people living in care homes by 47.8%. Based on current spend, related total expenditure on social care will increase by 94.1% (from 0.87% to 1.25% of GDP), with public expenditure increasing by 84.2% and private expenditure by 108.4% in real terms. Moreover, since men's IndLE65 will increase over the same period by 14.7% (range 11.3–16.5%), this will exceed the 8% equivalent of the Ageing Society Grand Challenge mission of five extra healthy and

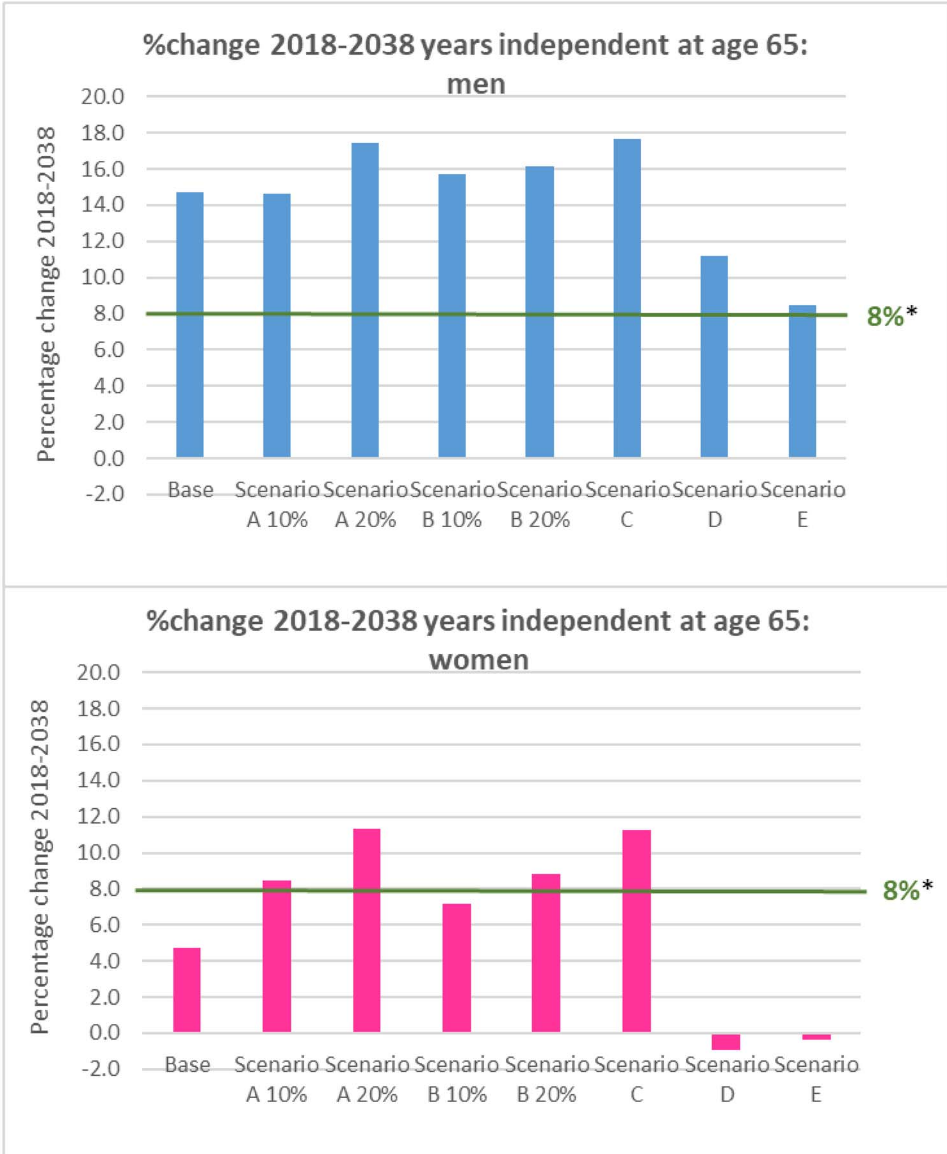

Figure 3. Change (%) between 2018 and 2038 in years independent at age 65, by gender.

independent years. The projected increase for women's IndLE65 however is only 4.7% (range 3.2%–5.8%).

The lowest projected increase over time in the number of people with ADL limitations, and in the number of care recipients, resulted from reducing all transitions to worse states and increasing transitions to recovery by 10% (Scenario C). Total care expenditure in 2038 will be £1.7 billion (11%) lower in this scenario than in the base case and increases in both men's and women's independent life expectancy at age 65 would exceed 8%. In contrast, the most pessimistic scenario (E) with increases in transitions to worse states, reductions in recovery, and lower LE, resulted in projected increases in total care expenditure in 2038 of £1.5 billion over the base case, and, although men's IndLE65 would still increase by over 8%, women's IndLE65 would reduce slightly. The difference in care expenditure between the most optimistic and pessimistic scenarios is £3.2 billion, or 0.11 GDP points in 2038. This is broadly equivalent to the total net expenditure spent by local authorities on community care for older people in 2018 (£3.0 billion).

Two recent reports have highlighted the need to harness strategies across the whole spectrum of ageing science, to realise the ideal of healthy ageing for all individuals [2, 18]. Not least in this is the management of long-term conditions (LTCs), and in particular multiple LTCs or multimorbidity, that are major contributors to functional decline [19, 20]. Uncovering common biological mechanisms between several LTCs could aid the development of new therapeutics, and better exploitation of existing clinical trial data by individual participant-level data meta-analyses to ascertain efficacy of pharmaceutical treatments in subgroups with comorbidities would provide more realistic, 'real world' evaluation [21–23]. The wider availability of assistive and digital technology to compensate for functional loss, enabling older people to continue to do the things to which they attribute personal value, will engender a culture of aspirational ageing [24]. In addition, life-space mobility, defined as the spatial area within which a person travels over a specified period in daily life, is intricately linked to social connectedness, poor quality of life and increased mortality [25]. Wider environmental endeavours such as nearby green space, outdoor recreational facilities within walking distance and the safety of outdoor environments will encourage older people to participate more in such activities [26]. Age-friendly public transport networks that serve both rural and urban communities plus adequate and appropriate housing stock that supports older people to maintain independence is also critical. Nevertheless, the design of assistive and digital technology, and recreational facilities will need to recognise the increased prevalence of multiple LTCs and dementia with age if they are to remain available for all ages.

Strengths and limitations

The strengths of our study are in the comprehensive nature of PACSim that addressed many of the limitations of previous microsimulation models [27–31]. These include: the three large, nationally representative surveys forming PACSim's base population; allowance for the joint effect of multiple diseases on disability; having the real health and disability status of new entrants to the older population, thereby requiring no assumptions. Strengths of the CPEC model include: the translation of dependency levels into social care use through linkage with PACSim, rather than inferring care needs from social care use; its detailed analysis of the relationship between needs and receipt of residential care, community care and unpaid care based on data from a large sample, with the analysis accounting for the complex two-way relationship between formal care and unpaid care, which increases the scientific rigour of projections for formal care.

Our study also has some limitations. Firstly, there is a lack of evidence of the level of reductions in the progression of disability/dependency from improvements in many of the factors mentioned earlier, for example multiple LTCs, frailty, cognitive impairment. We therefore had to base our scenarios on the effect of obesity and physical inactivity on disability progression, though this does give some indication of a plausible effect size for interventions to slow down progression to more severe levels or increase recovery to independence. Secondly, the CPEC projections are based on a series of key demographic and economic assumptions (see Appendix). As discussed elsewhere [5–6], alternative assumptions may affect projection results. Thirdly, our results use the 2018-based population projections, these being the most recent projections at the time. Though 2020-based projections are now available, they only account for the early months of the Covid-19 pandemic, and the effect of the pandemic on dependency and disability will require longitudinal data post Covid-19 that will not be available for some time. Lastly, as yet, we cannot provide confidence intervals around the outcomes from PACSim as this requires accounting for the error in the coefficients from transition models of the individual characteristics. We have, however, undertaken multiple runs of PACSim to provide some evidence of the range of the trends in outcomes although this neglects the error in transition models.

Policy implications

Previous studies of social care projections often assumed that the prevalence of disability by age and gender would remain constant over time [8, 32]. We show that even our most pessimistic scenario would lead to lower projections of demand for care and care expenditure than an assumption of unchanged prevalence of disability. It appears that younger cohorts of older people in England are likely to live longer and healthier lives than previous cohorts, prompting researchers and policy makers to consider carefully whether an assumption of constant prevalence rates of disability is the most appropriate base case for social care projections.

Interventions that slow down disability progression, as well as improving recovery, could significantly reduce the expected increase between 2018 and 2038 in numbers of older people with ADL limitations, numbers of care recipients and total expenditure on social care. Importantly, focussing first on protecting against decline, then on regaining a lost ability, and finally on compensating for a lost ability through assistive technology can help reshape an individual's ageing trajectory and ultimately the individual and societal cost of care [33]. High-quality care and interventions delivered by a competent workforce and improved infrastructure in primary and secondary care will be equally valuable. Government policies aiming to promote healthy ageing not only help to improve older people's later life wellbeing, but also to have a strong economic rationale. This would result in increases in independent life expectancy exceeding the UK government's Ageing Society Grand Challenge of increasing healthy, independent life years by 5 years by 2035. The resources saved on care could be spent on further interventions and improvements in the workforce and care infrastructure, which will enable healthy ageing and economic efficiency to benefit each other and form a virtuous cycle.

Supplementary Data: Supplementary data are available in Age and Ageing online.

Declaration of Conflicts of Interest: None.

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References

1. World Health Organization. Global strategy and action plan on ageing and health. Geneva: World Health Organization, 2017.
2. World Health Organization. Decade of healthy ageing: baseline report. Geneva: World Health Organization, 2020.
3. Department for Business, E.I.S. Policy paper: the Grand Challenge missions. 2021; Available from: https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions (13 January 2021, date last accessed).
4. Robine J-M, Jagger C, Crimmins EM, Saito Y, van Oyen H. Trends in health expectancies. In Jagger C, *et al.* eds. International Handbook of Health Expectancies. London: Springer, 2020; 19–34.
5. Welsh CE, Matthews FE, Jagger C. Trends in life expectancy and healthy life years at birth and age 65 in the UK, 2008-2016, and other countries of the EU28: an observational cross-sectional study. Lancet Regional Health 2021; 2: 100023.
6. Kingston A, Robinson L, Booth H *et al.* Projections of multi-morbidity in the older population in England to 2035: estimates from the population ageing and care simulation (PACSim) model. Age Ageing 2018; 47: 374–80.
7. Wittenberg R, Hu B, Hancock R. Projections of demand and expenditure on adult social care 2015 to 2040. Unit, Editor: P.S.S.R, 2018.
8. Wittenberg R, Knapp M, Hu B *et al.* The costs of dementia in England. Int J Geriatr Psychiatry 2019; 34: 1095–103.
9. Isaacs B, Neville Y. The needs of old people: 'interval' as a method of measurement. Br J Prev Soc Med 1976; 30: 79–85.
10. Kingston A, Jagger C. Population ageing and care simulation model (PACSim). Baseline dataset and model construction (version: 241017) Available at: https://goo.gl/nm8Rmk (23 June 2019, date last accessed).
11. Office for National Statistics. National population projections: 2018-based. 2019 07/01/2020]; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2018based (7 January 2020, date last accessed).
12. Office for National Statistics. Expectation of life, principal projection, England. 2019 07/01/2020]; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/datasets/expectationoflifeprincipalprojectionengland (7 January 2020, date last accessed).
13. Sullivan DF. A single index of mortality and morbidity. Health Serv Mental Health Admin Health Reports 1971; 86: 347–54.
14. Office for National Statistics. Health state life expectancies, UK:2017–2019. 2021 27/09/2021]; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/healthstatelifeexpectanciesuk/2016to2018.
15. Al Snih S, Ottenbacher KJ, Markides KS, Kuo Y-F, Eschbach K, Goodwin JS. The effect of obesity on disability vs mortality in older Americans. Arch Intern Med 2007; 167: 774–80.
16. Shah RC, Buchman AS, Leurgans S, Boyle PA, Bennett DA. Association of total daily physical activity with disability in community-dwelling older persons: a prospective cohort study. BMC Geriatr 2012; 12: 63. https://doi.org/10.1186/1471-2318-12-63.
17. Bennett HQ, Kingston A, Spiers G *et al.* Healthy ageing for all? Comparisons of socioeconomic inequalities in health expectancies over two decades in the cognitive function and ageing studies I and II. Int J Epidemiol 2021; 50: 841–51.
18. House of Lords Science and Technology Committee. Ageing: Science, Technology and Healthy Living House of Lords: The Science and Technology Select Committee, UK, 2021.
19. Pivetta NRS, Marincolo JCS, Neri AL, Aprahamian I, Yassuda MS, Borim FSA. Multimorbidity, frailty and functional disability in octogenarians: a structural equation analysis of relationship. Arch Gerontol Geriatr 2020; 86: 103931. https://doi.org/10.1016/j.archger.2019.103931.
20. Ryan A, Wallace E, O'Hara P, Smith SM. Multimorbidity and functional decline in community-dwelling adults: a systematic review. Health Qual Life Outcomes 2015; 13: 168–8.
21. Hanlon P, Hannigan L, Rodriguez-Perez J *et al.* Representation of people with comorbidity and multimorbidity in clinical trials of novel drug therapies: an individual-level participant data analysis. BMC Med 2019; 17: 201. https://doi.org/10.1186/s12916-019-1427-1.
22. Hughes MJ, McGettrick HM, Sapey E. Shared mechanisms of multimorbidity in COPD, atherosclerosis and type-2 diabetes: the neutrophil as a potential inflammatory target. Eur Respir Rev 2020; 29: 190102.
23. Mariani N, Borsini A, Cecil CAM *et al.* Identifying causative mechanisms linking early-life stress to psycho-cardio-metabolic multi-morbidity: the EarlyCause project. PLoS One 2021; 16: e0245475. https://doi.org/10.1371/journal.pone.0245475.
24. Soar J, Yu L, Al-Hakim L. Older people's needs and opportunities for assistive technologies. In: Jmaiel M *et al.*, eds. The Impact of Digital Technologies on Public Health in Developed and Developing Countries. ICOST 2020. Lecture Notes in Computer Science, vol 12157. Switzerland: Springer, 2020; 404–14.
25. Miyashita T, Tadaka E, Arimoto A. Cross-sectional study of individual and environmental factors associated with life-space mobility among community-dwelling independent older people. Environ Health Prevent Med 2021; 26: 9.
26. Eronen J, von Bonsdorff M, Rantakokko M, Rantanen T. Environmental facilitators for outdoor walking and development of walking difficulty in community-dwelling older adults. Eur J Ageing 2014; 11: 67–75.
27. Chen BK, Jalal H, Hashimoto H *et al.* Forecasting trends in disability in a super-aging society: adapting the future elderly model to Japan. J Econ Ageing 2016; 8: 42–51.
28. Goldman DP, Shang B, Bhattacharya J *et al.* Consequences of health trends and medical innovation for the future elderly. Health Aff 2005; 24: W5-R5. https://doi.org/10.1377/hlthaff.W5.R5.
29. Guzman-Castillo M, Ahmadi-Abhari S, Bandosz P *et al.* Forecasted trends in disability and life expectancy in England and Wales up to 2025: a modelling study. Lancet Public Health 2017; 2: e307–13.
30. Lay-Yee R, Pearson J, Davis P, von Randow M, Kerse N, Brown L. Changing the balance of social care for older

people: simulating scenarios under demographic ageing in New Zealand. Health Soc Care Community 2017; 25: 962–74.

31. Legare J, Decarie Y, Belanger A. Using microsimulation to reassess aging trends in Canada. Can J Aging 2014; 33: 208–19.

32. Chung RY, Tin KYK, Cowling BJ *et al.* Long-term care cost drivers and expenditure projection to 2036 in Hong Kong. BMC Health Serv Res 2009; 9: 172. https://doi.org/10.1186/1472-6963-9-172.

33. Gore PG, Kingston A, Johnson GR, Kirkwood TBL, Jagger C. New horizons in the compression of functional decline. Age Ageing 2018; 47: 764–8.

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