NIHR | Policy Research Unit Older People and Frailty

The contribution of single and multiple chronic conditions to the deteriorating time trends in later-life disability

Part 2: Single and multiple conditions

Holly Bennett, Fiona Matthews, Andrew Kingston, Louise Robinson, Martin Knapp, Carol Jagger

Full Report

September 2020

Project 1: The contribution of single and multiple chronic conditions to the deteriorating time trends in later-life disability

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Background

The UK Government's Ageing Society Grand Challenge aims to ensure everyone spends an extra five years healthy and independent by 2035[1]. Previously in this project, we reported that, between 1991 and 2011, both men and women at age 65 gained more years free of disability than years with disability, due to lower chances of developing disability for men and women, and lower chances of dying with disability for men. However, women reach the age at which the remaining years are divided equally between years with, and without, disability some 10 years earlier than men do [2].

In the second part of this project we seek to understand what is driving these DFLE gains, and identify gender differences. We focus on long-term conditions (the major drivers of disability [3]), and multiple long term conditions (MLTC), the prevalence of which appears to be increasing faster than would be expected from population ageing [4]. Knowing whether gains in years with disability are due to an increase in the prevalence of specific conditions or a rise in multiple conditions, and whether these explain differences between men and women, is important for informing treatment and preventive strategies. It will also inform social care approaches to support future cohorts of older adults requiring care.

Specifically, we again use longitudinal (follow-up over multiple time points) data from the Cognitive Function and Ageing Studies (CFAS I and II), to determine whether the extra years with disability are because a) individual long-term conditions have become more prevalent and/or more disabling; or b) MLTC have become more prevalent or disabling.

Methods

Data

The Cognitive Function and Ageing Studies (CFAS I and CFAS II) are two large population based studies of people aged 65 years or older living in England (CFAS I N=7635, CFAS II N=7762) [5]. Sampling strategy was identical for CFAS I and CFAS II. Individuals were identified through the primary care lists in three centres (Newcastle, Nottingham, Cambridgeshire) and included people living in care settings, semi-dependent housing and in the community. Sampling was stratified for those aged 65 to 74 years and those aged 75 or above. If someone agreed to participate an interviewer would visit them at their home to conduct the interview. Baseline interviews began in 1991 for CFAS I and in 2008 for CFAS II with follow up interviews conducted two years later. An informant interview was requested on a subsample of participants, weighted towards the frail and cognitively impaired. The participant would nominate a friend or family member who would complete an interview covering the same topics as the participant interview. This information could then be directly substituted for missing data from the participant interview. CFAS I and CFAS II received date of death from the Office for National Statistics routinely.

Measures

Impairment in activities of daily living (ADL) [6] determined level of disability in both studies. Disability was categorised into severe disability, mild to moderate disability and no disability. Severe disability was measured as needing help with either washing all over, preparing and cooking a hot meal, or putting on shoes and socks or if they were housebound. Mild to moderate disability was classified as needing help with heavy housework or shopping and

carrying heavy bags. A person was classified as not having any disability if they did not need help with any of the above and were not housebound.

All long-term conditions were self-reports by respondents of diagnoses made by doctors apart from cognition. Cognitive impairment was defined as a score less than 26 on the Mini-Mental State Examination [7], included in the CFAS interview. Other health conditions were: respiratory difficulties (either asthma except in childhood only, or chronic bronchitis), Coronary Heart Disease (CHD, either angina or heart attack), arthritis, diabetes, visual impairment, hearing difficulties, peripheral vascular disease (PVD) and stroke. In addition we defined MLTC as the presence of two or more health conditions; for those individuals with missing health conditions multi-morbidity was determined if the percentage of measured health conditions exceeded 22.2% (equivalent to 2 out of 9). Due to defining MLTC in this way, there were a few participants who had only one long-term condition recorded but were considered to have MLTC (CFAS I: 0.4%, 30/7635; CFAS II: 0.8% , 61/7762).

Statistical analysis

Logistic regression was used to compare prevalence of each health condition at baseline between the two studies and the extent to which age, sex and time contributed to differences seen in prevalence. All logistic regression models used non-response weights that included age, sex, deprivation and care home status, these being the main characteristics associated with non-response.

Population Attributable Fractions (PAFs) were calculated for incident disability at two years separately in CFAS I and CFAS II for each long-term condition. The PAF was estimated from fitting Poisson regression models with incident disability at two-year follow-up interview as the outcome and each long-term condition as covariate in separate models. The Poisson regression models were adjusted for longitudinal non-response using inverse probability weighting. The longitudinal inverse probability weights included age, sex, centre, cognition, disability, education, social class, deprivation, number of long-term conditions (different to percentage MLTC described above, this is a simple count), self-perceived health and smoking status. These were then combined with the baseline non-response weights. Person-years were calculated as the time between date of baseline interview and two-year follow-up interview for those who did not develop disability and as halfway between baseline and two-year follow-up interview if someone did develop disability. Those who did not complete the two-year follow-up interviews and those with disability at baseline were excluded from the PAF models but were accounted for in the weighting.

Life expectancies were estimated from longitudinal multistate models analysing transitions between no disability, disability and death in Interpolated Markov Chain (IMaCh) software version 0.99r19 [8]. IMaCh models discrete time steps, using multinomial logistic regression to model transition probabilities within each step. Initially length of time between interviews is used as the discrete time step (two years, 24 months) however, where possible, this is decreased to 1-month steps to approximate continuous time. For models stratified by sex and study exceptions to 1-month steps were stroke (12-month step); for between study comparisons, all models had 3-month steps apart from stroke and PVD which converged with 12-month steps. The life expectancy models were inverse probability weighted for participants included in the model. The weights for the life expectancy models differ to those for the PAF models as participants who died were included in the life expectancy models but

not in the PAF models. Anyone alive at the censor date, but who participated only at baseline, was excluded from the models. However, those excluded were more likely to have severe disability, which could lead to an underestimate of recovery and overestimate of mortality from disability. To account for this, additional weighting was applied to those who were alive by the censor date and participated in baseline and two year follow up interview. For further details see appendix. Total life expectancy (TLE) was modelled on date of death and for comparability between CFAS I and II, date of death was included up to two years after the two-year follow-up interview (four years follow-up in total). Disability-free life expectancy (DFLE) and life expectancy with disability (DLE) with and without each long-term condition (and MLTC) were estimated from the multistate models described above with each health condition as covariate. Analysis was undertaken separately for men and women in CFAS I and CFAS II.

Results

Demographics

There were 7635 participants in the CFAS I baseline interviews, 60.8% were women and the average age at interview was 75.6 years. Out of the baseline participants 10.7% (n= 819) had died before the two-year follow-up interview and of those still alive 76% (5156/6816) participated in the two-year follow-up interview, the remaining 1660 having moved away or refused. Of the 7762 participants at baseline in CFAS II, 56.1% were women and average age was 76.4 years. A lower percentage of baseline participants in CFAS II died before two-year follow-up interview (8.3%, n=643) and out of the 7119 people who were still alive 74% (n=5288) agreed to another interview, with 1831 refusing or having moved away.

Prevalence of long-term conditions at age 65 years and over

The prevalence of most long-term conditions in those aged 65 years and over increased between CFAS I and CFAS II, whilst cognitive impairment was the only condition to show a decrease over the period (Table 1). For CHD, diabetes, hearing difficulties, PVD, and cognitive impairment these changes were not simply a result of differences in the age and sex distributions of the CFAS I and II populations (Appendix Table 1). Additionally, the prevalence of CHD, diabetes, and PVD increased and the prevalence of cognitive impairment decreased across all age groups, whilst the prevalence of arthritis and stroke increased in the oldest age group only, with increases in vision impairment and hearing difficulties seen in the youngest age groups with small improvements in the oldest age groups (Table 1). The prevalence of respiratory difficulties was similar between the two studies, but this hid increases in the 75-84 years age group and decreases in those aged 85 years and over.

MLTC increased in the younger age groups but was similar in the oldest age group (Table 1).

In order to better understand how the presence of other conditions might affect changes in the prevalence of individual long-term conditions between CFAS I and CFAS II, we investigated the prevalence of MLTC in those with each long-term condition (Appendix Table 2). In general the prevalence of MLTC was high in those with all individual conditions for both CFAS I and CFAS II. The greatest difference in prevalence of MLTC between CFAS I

and II was an increase of seven percentage points for men with arthritis, and six percentage points for men and five for women with cognitive impairment.

Table 1: Prevalence (%) of long-term conditions by age in CFAS I and CFAS II

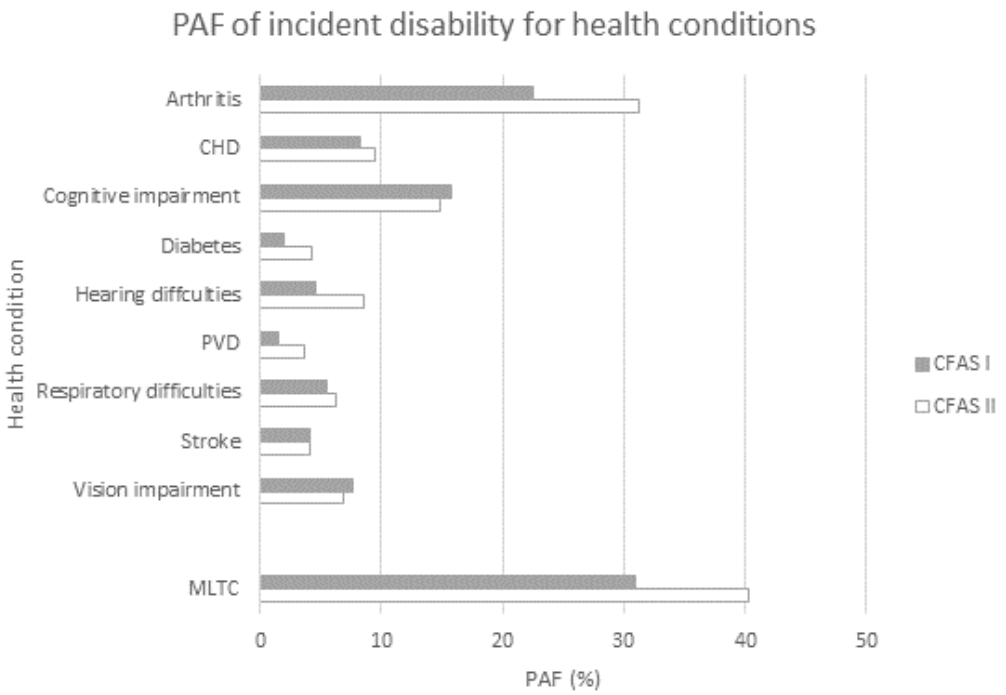
	65-74		75-84		85+		All ages	
	CFAS I %	CFAS II %	CFAS I %	CFAS II %	CFAS I %	CFAS II %	CFAS I %	CFAS II %
Arthritis	50.0	50.1	55.3	57.1	57.0	64.2	52.9	55.0
CHD	15.7	16.3	19.7	24.9	19.7	26.3	17.7	21.0
Cognitive impairment	23.4	15.9	44.4	30.6	72.6	50.6	37.5	26.8
Diabetes	5.3	14.1	7.6	16.1	5.5	11.6	6.2	14.5
Hearing difficulties	15.2	19.6	24.4	28.6	45.4	43.5	22.5	26.9
PVD	4.0	10.2	4.6	11.3	4.0	10.8	4.3	10.7
Respiratory problems	20.0	19.8	18.3	20.5	19.2	16.4	19.2	19.5
Stroke	5.6	6.2	10.1	10.4	10.6	13.2	8.0	8.9
Vision impairment	7.1	11.4	15.9	15.1	32.7	26.8	13.6	15.2
MLTC[1]	42.8	47.1	61.1	63.9	77.6	75.4	54.3	58.1

[1]Multiple long-term conditions (multimorbidity)

Population attributable risk of disability for health conditions

The population attributable fraction (PAF) estimates the percentage of new (incident) disability cases over the two year follow-up that are associated with each long-term condition. With the exception of cognitive impairment and stroke each health condition was associated with a greater percentage of incident disability cases in CFAS II compared to CFAS I (Figure 1). MLTC was associated with 30.9% of incident disability cases in CFAS I, increasing to 40.3% in CFAS II (Figure 1).

Figure 1: Population Attributable Fraction (PAF) of incident disability for each long-term condition and multiple long-term conditions (MLTC), unadjusted



Life expectancy and disability-free life expectancy at age 65 with single health conditions

We have previously reported that in the period between CFAS I and CFAS II men's total life expectancy (TLE) at age 65 increased by 4.6 years (95% confidence interval (CI) 3.7 to 5.5 years) of which the majority, 3.7 years (95%CI 2.7 to 4.8 years) were years free of disability [2]. The majority of LE gain being in DFLE than in years with disability (DLE) was also the case in the presence of most long-term conditions (Figure 2, Appendix Table 3) resulting in the percentage of remaining years spent disability-free at age 65 being similar in CFAS II to CFAS I (Appendix Table 4). Men with respiratory difficulties (4.9 years) and men living post-stroke (4.5 years) experienced the greatest improvements in DFLE (Figure 2). Men with cognitive impairment experienced the smallest increase in DFLE (1.8 years), and a similar level of increase in DLE, despite a reduction in the prevalence of cognitive impairment.

Comparing TLE and DFLE for men with and without each long-term condition provides understanding of how the fatality and disabling effects of conditions have changed between CFAS I and II. In CFAS I the largest difference was for men with stroke who had a TLE 5.2 years less than men without stroke and DFLE of 6.0 years less. However by CFAS II the difference associated with cognitive impairment (TLE: 3.8 years less, DFLE: 5.0 years less) and stroke (TLE: 3.6 years less, DFLE: 5.1 years less) were comparable (Figure 3, Appendix Table 3). Arthritis also made a greater contribution to loss of DFLE in CFAS II than in CFAS I whilst respiratory difficulties contributed less to the loss of both TLE and DFLE in CFAS II. There was little change in the loss of years in TLE and DFLE between CFAS I and II for the remaining health conditions.

Figure 2: Disability-free life expectancy and life expectancy with disability at age 65 for men with a health condition in CFAS I and CFAS II

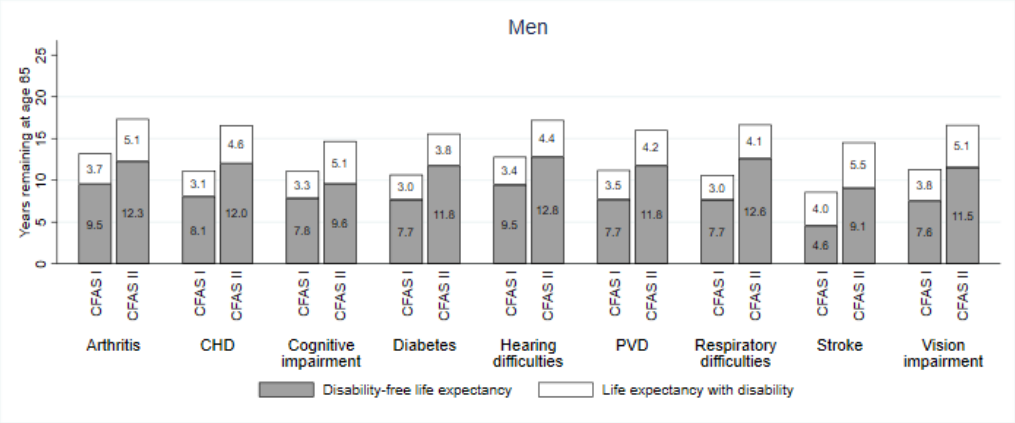
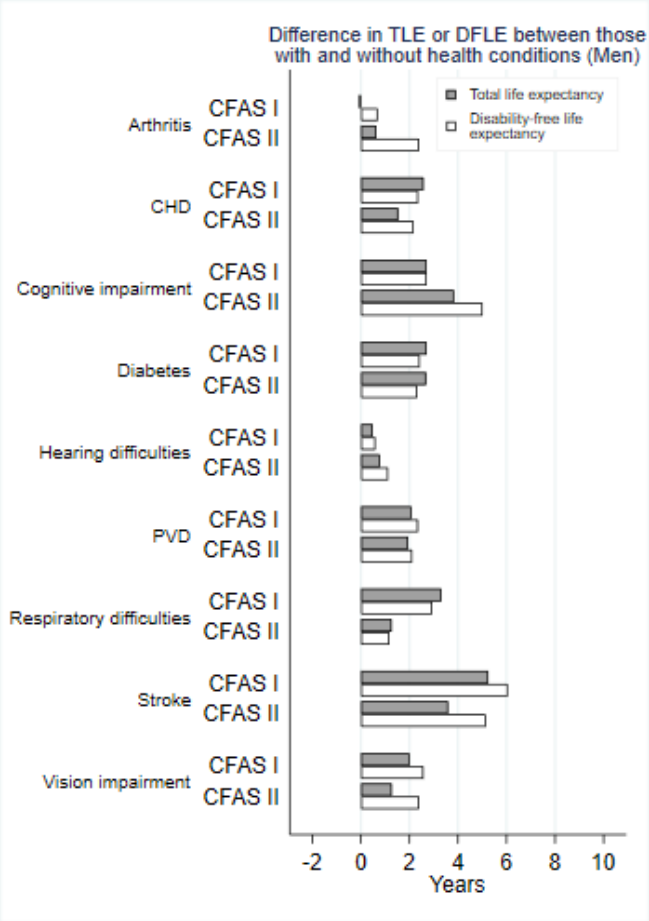


Figure 3: Difference in total life expectancy (TLE) and disability-free life expectancy (DFLE) between men with and without the health condition (TLE or DFLE without health condition – TLE or DFLE with health condition) CFAS I and CFAS II



Between CFAS I and II, women experienced an increase in LE at age 65 of 2.1 years (95%CI 1.1 to 3.0 years), with an almost equal increase in DFLE of 2.0 years (95%CI 1.0 to 2.9 years). Similarly to men, the majority of gains in LE at age 65 for women with each long-term condition have been in disability-free years.

While there was no reduction in years with disability (DLE) for men with health conditions, women with some conditions saw a reduction in DLE (Figure 4, Appendix Table 5). For example, women with CHD experienced a decline in DLE (CFAS I: 9.2 years, CFAS II: 8.1 years). The largest gains in DFLE occurred in women with stroke (3.5 years, Figure 4), but this gain was not as large as for men (4.5 years, Figure 2). Women with cognitive impairment in CFAS II experienced more years of disability (8.4 years) than CFAS I (7.6 years) with no improvement to years spent disability-free (Figure 4, Appendix Table 5). Consequently, the percentage of remaining years with disability was greater for women with cognitive impairment in CFAS II (51.5%) compared to CFAS I (47.5%) (Appendix Table 6).

Comparing TLE and DFLE for women with and without each long-term condition shows that, in CFAS I, the difference in TLE and DFLE was largest between women with and without stroke followed by diabetes. By CFAS II the difference in TLE and DFLE between women with and without cognitive impairment was comparable to diabetes or stroke (Figure 5, Appendix Table 5). The difference in TLE between women with and without CHD increased

between CFAS I and CFAS II but the difference in DFLE decreased. This is in contrast to men with and without CHD where the difference in TLE and DFLE declined for both between CFAS I and II.

Figure 4: Disability-free life expectancy and life expectancy with disability at age 65 for women with a long-term condition in CFAS I and CFAS II

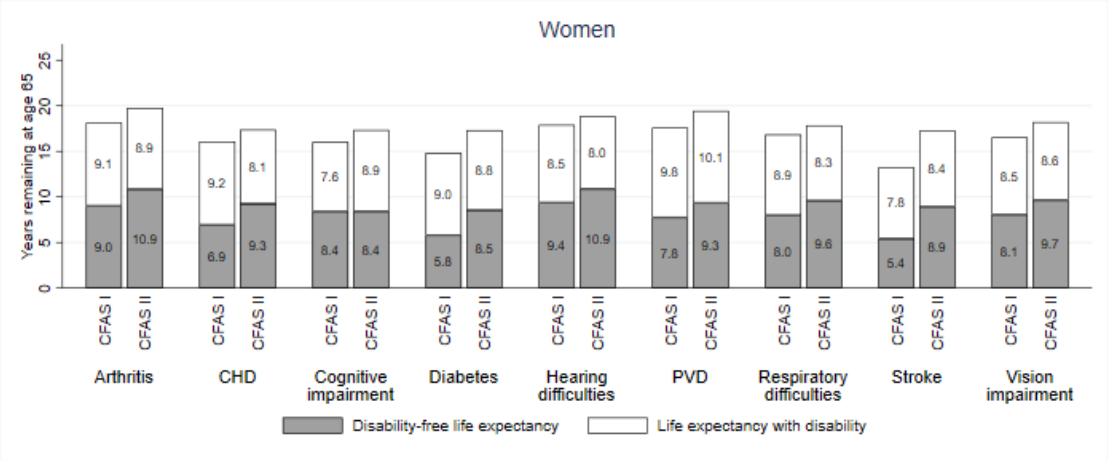
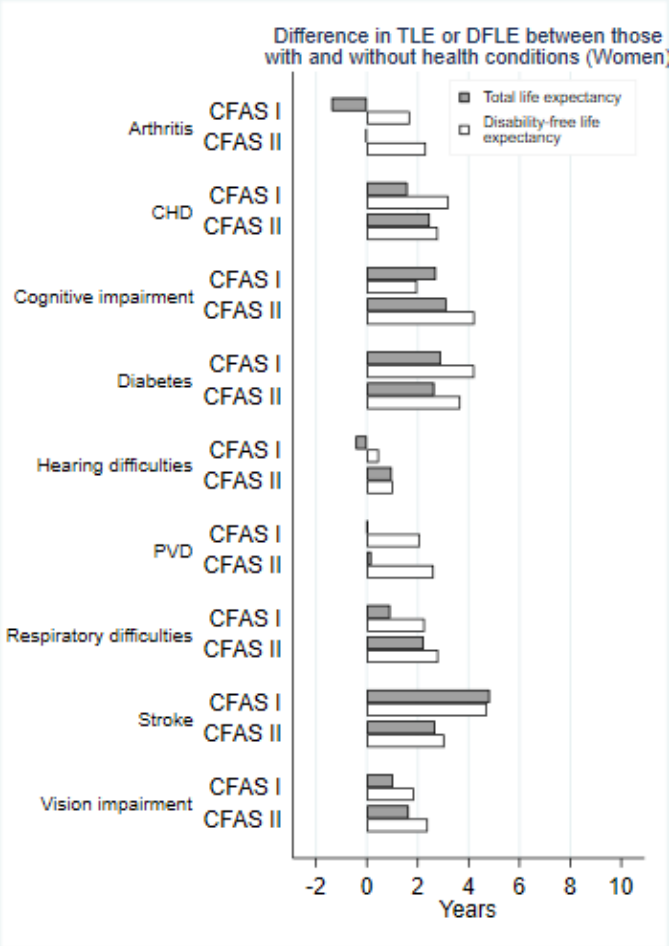


Figure 5: Difference in total life expectancy (TLE) and disability-free life expectancy (DFLE) between women with and without the long-term condition (TLE or DFLE without condition – TLE or DFLE with condition) CFAS I and CFAS II



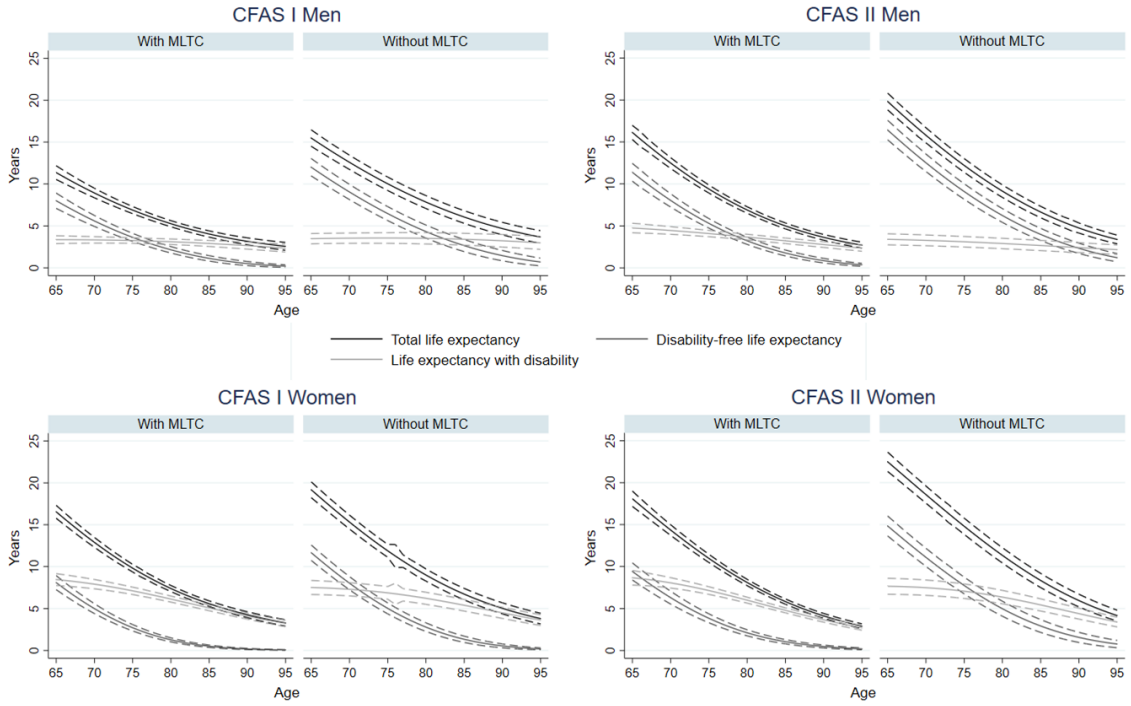
We have previously focused on the age at which the remaining years spent free of disability and with disability are equal (DFLE50%), as a useful way of seeing how DFLE and DLE change across the age range. Given the different effect on DFLE for men with, and women with cognitive impairment between CFAS I and CFAS II we examined DFLE50% (Appendix Figure 1). For men with cognitive impairment DFLE50% decreased from 75 years in CFAS I to 74 years in CFAS II, with a similar decrease for women with cognitive impairment from 66 years in CFAS I to <65 years in CFAS II. In contrast, for men and women without cognitive impairment DFLE50% increased by 5 years for men (CFAS I: 80 years; CFAS II: 85 years) and women (CFAS I: 67 years; CFAS II: 72 years).

Life expectancy and disability-free life expectancy at age 65 with multiple long-term conditions (MLTC)

Between CFAS I and CFAS II, gains in LE at age 65 for men with MLTC (4.7 years) were mostly gains in DFLE (3.4 years) (Appendix Table 3). For women the gain in DFLE at age 65 (1.3 years) exceeded gains in TLE (0.7 years) (Appendix Table 5) resulting in an increase in the percentage of years spent disability-free (Appendix Table 6).

Between CFAS I and CFAS II, the DFLE50% increased only slightly for men and women with MLTC (men: from age 76 to 78; women: from age <65 to 66) (Figure 6). However larger increases were evident, particularly for men without MLTC, so that by CFAS II men without MLTC took 11 years longer to reach DFLE50% than men with MLTC (89 vs. 78). In CFAS II DFLE50% for women without MLTC was 10 years greater than for women with MLTC (76 vs. 66) (Figure 6).

Figure 6: Total life expectancy, disability-free life expectancy and life expectancy with disability over ages 65 to 95 years for men and women in CFAS I and CFAS II with and without multiple long-term conditions (MLTC)



Probability of transitioning between disability states and death by long-term condition

The large improvements in DFLE seen in men with respiratory difficulties (4.9 years) appear to be a result of a decrease in the probability of death from a disability-free state. Similar sized improvements in DFLE in men with stroke (4.5 years) potentially resulted from a

decrease in the probability of death from a disability state, although the probability of incident disability was halved for men with stroke between CFAS I and CFAS II (Appendix Table 7).

Men with cognitive impairment experienced the smallest increase in DFLE (1.8 years) with the same sized increase in DLE (men with other health conditions having increase in DFLE greater than increase in DLE), likely resulting from reductions in the probability of death from a disability-free state, without improvement in other transitions.

Men with other individual health conditions (hearing difficulties, respiratory difficulties or vision impairment) also experienced reductions in the probability of death from a disability-free state. In all these cases, but not in men with cognitive impairment, there was also a reduction, albeit not statistically significant, in the probability of incident disability (Appendix Table 7). Significant reductions in the probability of incident disability (no disability to disability) between CFAS I and CFAS II were only evident for men with CHD (RRR: 0.7, 95% CI: 0.5 – 0.9).

Women with CHD experienced a decline in DLE (CFAS I: 9.2 years, CFAS II: 8.1 years), possibly because of a decline in the likelihood of transitioning to disability (RRR: 0.6, 95% CI: 0.4 – 0.8) (Appendix Table 7). In addition, women with arthritis, hearing difficulties, respiratory difficulties, or vision impairment were less likely to transition to disability in CFAS II compared to CFAS I (Appendix Table 7).

The largest gains in DFLE occurred in women with stroke (3.5 years), and this was probably due to the substantial, though non-significant, increase in the probability of recovery (transition from disability to no disability) (Appendix Table 7). Women with cognitive impairment experienced no improvement in DFLE between CFAS I and CFAS II and an increase of 0.7 years with disability, although there was no evidence of significant increases or reductions in any of the transitions (Appendix Table 7). For women with long-term conditions, the only evidence of differences in the probability of death across the studies was for women with PVD where the probability of death with disability halved between the studies (RRR: 0.5, 95% CI: 0.3 – 0.8) (Appendix Table 7).

To better understand how the disabling and fatal effects of long-term conditions had changed between CFAS I and CFAS II, we undertook analyses to produce the relative risk ratios for those with each condition (compared to those without the condition), separately for men and women and by study.

In CFAS I stroke was the largest contributor to loss of years in men's TLE (5.2 years less) and DFLE (6.0 years less), and remained a major contributor to loss in DFLE in CFAS II (5.1 years less) although the loss in TLE between men without and with stroke was lower (3.6 years less). Men with stroke were more likely to transition to disability (than men without stroke) in both CFAS I (RRR: 2.2, 95% CI: 1.4 – 3.5) and CFAS II (RRR: 3.6, 95% CI: 2.3 – 5.6). Men with stroke were also less likely to recover from disability than men without stroke in both studies (CFAS I RRR: 0.5, 95% CI: 0.2 – 1.0, CFAS II RRR: 0.5, 95% CI: 0.3 – 0.9) (Appendix Table 8).

Other notable differences in loss of DFLE between those with and without long-term conditions were evident for men with cognitive impairment, arthritis and respiratory difficulties. The increase in loss of DFLE for men with cognitive impairment in CFAS II,

compared to CFAS I, appears to result from a greater likelihood of men with cognitive impairment transitioning to disability in CFAS II (RRR: 1.9, 95% CI: 1.1 – 2.0) but not in CFAS I. The greater contribution to reduction in DFLE for men with arthritis in CFAS II appeared to be due to a greater likelihood of transitioning to disability in CFAS II (RRR: 1.6, 95% CI: 1.2 – 2.1). The smaller contribution to DFLE loss for men with respiratory difficulties in CFAS II, compared to CFAS I, apparently results from a greater likelihood for them to die from a disability-free state in CFAS I (RRR: 1.6, 95% CI: 1.1 – 2.4), but from a disability state in CFAS II (RRR: 1.4, 95% CI: 1.1 – 1.7) (Appendix Table 8).

For women in CFAS I, stroke followed by diabetes were associated with the largest reductions to women's TLE and DFLE, but by CFAS II cognitive impairment was associated with a greater reduction to TLE and DFLE than diabetes or stroke. Women with stroke were more likely, compared to women without stroke, to transition to disability in CFAS I (RRR: 2.0, 95% CI: 1.3, 3.1) and CFAS II (RRR: 1.7, 95% CI: 1.0 – 3.0) (Appendix Table 8). Compared to women without diabetes, women with diabetes were more likely to transition to disability in both CFAS I (RRR: 1.6, 95% CI: 1.1 – 2.3), and CFAS II (RRR: 1.6, 95% CI: 1.2 – 2.2), but were more likely to die from a disability-free state in CFAS I (RRR: 2.9, 95% CI: 1.1 – 7.7) only (Appendix Table 8). The greater contribution to loss in TLE and DFLE for women with cognitive impairment in CFAS II compared to CFAS I perhaps resulted from women with cognitive impairment being more likely to transition to disability (RRR: 1.5, 95% CI: 1.2 – 2.0) in CFAS II only, as they were more likely to die from a disability state in CFAS I (RRR: 1.4, 95% CI: 1.2 – 1.6), as well as CFAS II (RRR: 1.2, 95% CI: 1.1 – 1.4) (Appendix Table 8).

Probability of transitioning between disability states and death by multiple long-term conditions (MLTC)

For men with MLTC, there were gains in DFLE between CFAS I and CFAS II (3.4 years) but these were less than the gains in TLE (4.7 years), since men with MLTC were less likely to die from either a disability-free (RRR: 0.5, 95%CI 0.3 – 0.7), or disability state (RRR: 0.7, 95%CI 0.6 – 0.9), in CFAS II compared to CFAS I (Table 2). For women with MLTC the gain in DFLE (1.3 years) exceeded the gains in TLE (0.7 years), feasibly from being less likely to transition to disability in CFAS II than CFAS I (RRR: 0.7, 95%CI 0.6 – 0.8) (Appendix Table 7).

When comparing men or women with MLTC to those without MLTC, men with MLTC were more likely to transition to disability in both studies (CFAS I RRR: 1.9, 95% CI: 1.4 – 2.4, CFAS II RRR: 2.4, 95% CI: 1.7 – 3.2), but only more likely to die in CFAS I (RRR: 1.4, 95% CI 1.1 – 1.7) (Appendix Table 8). In contrast, although women with MLTC were also more likely to transition to disability in both studies (CFAS I RRR: 1.7, 95% CI: 1.4 – 2.0, CFAS II RRR: 1.7, 95% CI: 1.3 – 2.1), they were less likely to recover in CFAS II (RRR: 0.5, 95% CI: 0.4 – 0.7) (Appendix Table 8).

Discussion

Between 1991 and 2011, the prevalence of most long-term conditions increased. For CHD, diabetes, PVD, and hearing difficulties this was not simply a result of the differences in the age and sex distributions in the populations. Nevertheless multiple long-term conditions

increased only in the youngest age group (age 65-74 years). Only cognitive impairment showed a decrease in prevalence of 40% even after adjusting for the ageing of the populations.

Despite increases in prevalence in many of the long-term conditions, and for both men and women, the increase in years free of disability at age 65 exceeded years with disability. Again the exception was for men and women with cognitive impairment where years gained with and without disability were equal, resulting in part from a greater likelihood of transitioning to disability in CFAS II but not CFAS I, when compared to men and women without cognitive impairment.

When multiple conditions were present, men aged 65 gained 4.7 years of life expectancy and 3.4 years extra free of disability, resulting from a lower risk of death from either disability state in CFAS II compared to CFAS I. Despite women aged 65 gaining fewer years of life in total (0.7 years) than men, women experienced compression of disability as the gain in DFLE (1.3 years) exceeded the gain in LE, resulting from a lower risk of transitioning to disability in CFAS II than CFAS I.

The increasing prevalence of long-term conditions, particularly stroke and diabetes, in the last decades has already been documented, at least in the UK and the US [9, 10], and is not simply a result of the ageing of populations [4]. Additionally, both countries, and others, report decreasing prevalence of cognitive impairment and dementia, although these findings are not universal [11].

Whether disability-free life expectancy trends are improving (with compression of disability) or not (expansion of disability) is more controversial, although our previous report for this project documented gains in DFLE at age 65 for both men and women, and gains in years with disability for men. These were due to decreases in the probability of developing disability for men and women, and a 50% lower risk of death from no disability for men [2].

Although long-term conditions are major drivers of disability, our study is the first to quantify the contribution of chronic conditions to trends in DFLE using longitudinal data. Other studies have quantified the contribution of long-term conditions to DFLE at a single time point, albeit mostly with cross-sectional data, and generally a single condition, particularly stroke, diabetes and sensory impairment [12-14]. The impact of multiple long-term conditions on DFLE has been studied less [15].

Of the long-term conditions we considered, the only one for which prevalence has decreased is cognitive impairment. Despite this, the negative impact of cognitive impairment on DFLE appeared greater in CFAS II than CFAS I. This could be due to the greater prevalence of other long-term conditions being present in those with cognitive impairment in CFAS II compared to CFAS I, although this amounted to only five or six percentage points on an already large proportion (over 80%) of those with cognitive impairment having multiple long-term conditions. Furthermore, we have already documented increasing inequalities over time in DFLE between the advantaged and disadvantaged, whether defined by deprivation or education [16]. Higher education is especially related to slower cognitive decline [17]. Ideally, we would have stratified analyses by the presence (or not) of other conditions, and also by education, but numbers in these groups were insufficient for models to converge.

Strengths and Limitations

CFAS I and II have identical sampling frames so are well placed to provide temporal comparisons, giving accurate estimates of changes over two decades without compromising the validity of results. Both CFAS I and CFAS II are large population based studies, which meant that a broad range of health conditions were able to be included even when prevalence was relatively low, and this in turn meant that multi-morbidity could be studied.

The limitations of this analysis relate to self-reported health conditions, missing data, and restrictions with the analyses. The presence of health conditions depends on self-report by the participant, which therefore relies on their memory and accuracy of reporting. However, missing information from the participant was substituted by information given by informants to limit the loss of data from this in both CFAS I and CFAS II. Even so, there were participants without responses to all nine health conditions. Given that those with missing data were more likely to be in ill-health, the multi-morbidity measure was based on percentage of conditions seen out of health conditions measured instead of a count (pro-rata estimation). Severity of disability could not be modelled as the number of transitions from severe disability to disability-free was too low and all transitions must exist within the multi-state model in the IMaCh software.

Implications for policy and practice

Our analyses present potentially informative findings for clinical practice in terms of the fatal and disabling effects of long-term conditions over time, and differences between men and women. The assumption that our ageing societies would lead to longer lives lived with increasing morbidity, disability and dependency may be misplaced. The key findings of this report, that increasing disability-free years is possible even in the presence of morbidity, has considerable implications for national policy and practice, particularly the gender differences in the gains in life expectancy and disability-free life expectancy for men and women with particular conditions such as CHD. Over the period of our study, the gain in life expectancy experienced by men with CHD was even greater than that experienced by men without CHD, so that the difference in life expectancy between men with and men without CHD reduced. This was not the case for women with CHD who had lower gains in LE than women without CHD, since women with CHD were three times more likely to die from a non-disabled state in CFAS II. This excess mortality was not evident in men. These findings confirm other studies showing that the incidence of fatal CHD is higher in older women than men [18]. Recognising the existence of such gender differences is crucial for improving the prevention, diagnosis, treatment and management of CHD in women.

In terms of care provision, the focus of future interventions and services should be on the prevention/reduction of disability as a long-term goal. This is particularly the case for women in general, and men and women with stroke and cognitive impairment, and women with diabetes, who have the largest reductions in DFLE compared to men and women without these conditions. Better integrated, health and social care provision, facilitating older people to remain independent and living in their own homes for as long as possible, should be the norm not the exception [19].

Conclusions

Between CFAS I and CFAS II

- The prevalence of multiple long-term conditions (defined as two or more) increased only in the youngest age group (age 65-74 years).
- LE at age 65 increased 4.7 years and DFLE by 3.4 years for men with multiple long-term conditions (MLTC), whilst women with MLTC gained 0.7 years in LE, and 1.3 years in DFLE, showing that it is possible to increase DFLE even in the presence of multiple long term conditions.
- The odds of reporting diabetes and PVD more than doubled, CHD and hearing difficulties increased by 20%, and cognitive impairment reduced by 40%, even after allowing for differences in the age and sex structure of the studies.
- The percentage of incident disability associated with each long-term condition singly (and multiple conditions) increased, with the exception of cognitive impairment and stroke.
- LE and DFLE at age 65 for men with each long-term condition increased, with gains in LE ranging from 3.5 to 6.0 years, and in DFLE from 1.8 to 4.9 years; for women gains in LE with each condition were small, with, in some cases, a slight decrease, whilst gains in DFLE ranged from 0 to 3.5 years. Thus, the years gained disability-free (DFLE) exceeded those gained with disability (DLE) for men and women with most long-term conditions.
- The years gained in DFLE and DLE were equal for men with cognitive impairment, but all gains in women with cognitive impairment were years with disability.

We have not, as yet, been able to conduct analyses with the disability measure disaggregated into none, mild or moderate/severe, due to the low number of some transitions. Such analyses could give further insight into the role of long term conditions and whether they impact years with mild disability or years with moderate/severe disability, further informing strategies to increase healthy and independent years of life.

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Appendix

Appendix Table 1: Odds ratios from logistic regression with prevalent long-term condition at baseline in CFAS I or CFAS II as the outcome and adjusted for sex, study and age group

	Sex			Study			Age group[1]														
							70-74			75-79			80-84			85-89			90+		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Arthritis	1.9	(1.8,	2.0)	1.1	(1.0,	1.2)	1.2	(1.1,	1.4)	1.3	(1.2,	1.5)	1.5	(1.3,	1.6)	1.7	(1.5,	2.0)	1.7	(1.4,	2.0)
CHD	0.6	(0.6,	0.7)	1.2	(1.1,	1.3)	1.3	(1.1,	1.4)	1.7	(1.5,	1.9)	2.1	(1.8,	2.3)	2.5	(2.2,	2.9)	3.6	(3.0,	4.4)
Cognitive impairment	1.4	(1.3,	1.5)	0.6	(0.5,	0.6)	1.4	(1.2,	1.6)	2.3	(2.1,	2.6)	4.0	(3.5,	4.5)	6.8	(5.9,	7.8)	13.1	(10.6,	16.2)
Diabetes	0.8	(0.7,	0.9)	2.4	(2.2,	2.7)	1.3	(1.1,	1.5)	1.6	(1.4,	1.9)	1.5	(1.3,	1.8)	1.7	(1.4,	2.0)	1.5	(1.1,	2.0)
Hearing difficulties	0.7	(0.7,	0.8)	1.2	(1.1,	1.3)	1.2	(1.0,	1.3)	1.5	(1.4,	1.7)	2.5	(2.2,	2.8)	3.6	(3.2,	4.2)	6.5	(5.4,	7.9)
PVD	0.8	(0.8,	0.9)	2.2	(1.9,	2.4)	1.2	(1.0,	1.5)	1.5	(1.2,	1.7)	1.5	(1.3,	1.8)	2.4	(1.9,	2.9)	2.5	(1.9,	3.3)
Respiratory difficulties	1.2	(1.1,	1.3)	1.0	(1.0,	1.1)	1.0	(0.9,	1.1)	1.0	(0.9,	1.1)	1.0	(0.9,	1.2)	1.2	(1.0,	1.4)	1.0	(0.8,	1.3)
Stroke	0.8	(0.7,	0.9)	1.1	(1.0,	1.3)	1.5	(1.2,	1.8)	2.3	(1.9,	2.7)	2.7	(2.3,	3.3)	3.9	(3.2,	4.8)	4.3	(3.3,	5.5)
Vision impairment	1.3	(1.2,	1.4)	1.1	(1.0,	1.2)	1.1	(1.0,	1.3)	1.6	(1.4,	1.9)	2.3	(2.0,	2.7)	3.7	(3.1,	4.3)	7.2	(5.9,	8.9)
MLTC[2]	1.1	(1.0,	1.1)	1.1	(1.0,	1.1)	1.4	(1.3,	1.6)	2.1	(1.9,	2.3)	3.1	(2.8,	3.4)	4.2	(3.6,	4.8)	6.2	(4.9,	7.7)

[1] Reference category for age group is 65-69 years [2] Multiple long-term conditions (multimorbidity)

Appendix Table 2: Prevalence of multiple long-term conditions (two or more) in people with each long-term condition, by sex and study

	Men		Women	
	CFAS I	CFAS II	CFAS I	CFAS II
Arthritis	72.5	79.6	73.6	75.7
CHD	85.1	87.5	92.0	93.3
Cognitive impairment	81.1	87.5	83.6	88.8
Diabetes	84.9	86.9	91.0	91.2
Hearing difficulties	87.7	85.1	92.5	91.3
PVD	88.7	92.8	94.2	96.6
Respiratory problems	83.0	87.2	88.4	90.2
Stroke	90.1	89.8	91.8	95.5
Vision impairment	92.4	89.1	94.3	91.8

Appendix Table 3: Total life expectancy, Disability-free life expectancy and life expectancy with disability with 95% confidence intervals (95% CI) at age 65 for men with and without long-term conditions in CFAS I and CFAS II

		CFAS I								CFAS II							
		TLE	TLE 95% CI		DFLE	DFLE 95% CI		DLE	DLE 95% CI		TLE	TLE 95% CI		DFLE	DFLE 95% CI		DLE	DLE 95% CI	
Arthritis	No	13.2	(12.4,	13.9)	10.2	(9.4,	11.1)	2.9	(2.5,	3.3)	18.0	(17.2,	18.8)	14.7	(13.7,	15.6)	3.3	(2.9,	3.8)
	Yes	13.2	(12.4,	14.1)	9.5	(8.6,	10.5)	3.7	(3.2,	4.2)	17.4	(16.5,	18.3)	12.3	(11.3,	13.3)	5.1	(4.4,	5.8)
	Diff.	-0.1	(-1.3,	1.1)	0.7	(-0.6,	2.0)				0.6	(-0.6,	1.8)	2.4	(1.0,	3.8)			
CHD	No	13.8	(13.0,	14.5)	10.4	(9.6,	11.2)	3.3	(2.9,	3.7)	18.1	(17.4,	18.9)	14.2	(13.3,	15.1)	4.0	(3.5,	4.4)
	Yes	11.2	(10.2,	12.2)	8.1	(7.1,	9.1)	3.1	(2.5,	3.7)	16.6	(15.5,	17.7)	12.0	(10.7,	13.3)	4.6	(3.8,	5.4)
	Diff.	2.6	(1.3,	3.8)	2.4	(1.0,	3.7)				1.5	(0.2,	2.9)	2.2	(0.6,	3.7)			
Cognitive impairment	No	13.8	(13.1,	14.6)	10.5	(9.8,	11.3)	3.3	(2.9,	3.7)	18.5	(17.8,	19.3)	14.6	(13.8,	15.4)	4.0	(3.5,	4.4)
	Yes	11.2	(10.1,	12.2)	7.8	(6.7,	9.0)	3.3	(2.7,	4.0)	14.7	(13.4,	16.0)	9.6	(7.8,	11.3)	5.1	(4.3,	6.0)
	Diff.	2.7	(1.4,	4.0)	2.7	(1.3,	4.1)				3.8	(2.3,	5.3)	5.0	(3.1,	6.9)			
Diabetes	No	13.4	(12.7,	14.1)	10.1	(9.4,	10.8)	3.3	(2.9,	3.7)	18.3	(17.6,	19.0)	14.1	(13.3,	14.9)	4.2	(3.8,	4.6)
	Yes	10.7	(9.1,	12.3)	7.7	(6.0,	9.4)	3.0	(2.0,	4.1)	15.6	(14.4,	16.8)	11.8	(10.4,	13.2)	3.8	(3.0,	4.7)
	Diff.	2.7	(0.9,	4.5)	2.4	(0.6,	4.3)				2.7	(1.3,	4.1)	2.3	(0.7,	3.9)			
Hearing difficulties	No	13.3	(12.6,	14.0)	10.1	(9.3,	10.8)	3.3	(2.9,	3.6)	18.0	(17.3,	18.7)	13.9	(13.1,	14.8)	4.1	(3.6,	4.5)
	Yes	12.8	(11.7,	14.0)	9.5	(8.2,	10.7)	3.4	(2.7,	4.0)	17.2	(16.1,	18.3)	12.8	(11.5,	14.2)	4.4	(3.7,	5.1)
	Diff.	0.5	(-0.9,	1.8)	0.6	(-0.9,	2.1)				0.8	(-0.5,	2.1)	1.1	(-0.5,	2.7)			
PVD	No	13.3	(12.7,	14.0)	10.1	(9.3,	10.8)	3.3	(2.9,	3.6)	18.0	(17.3,	18.6)	13.9	(13.1,	14.7)	4.1	(3.7,	4.5)
	Yes	11.2	(9.4,	13.1)	7.7	(5.9,	9.6)	3.5	(2.3,	4.8)	16.0	(14.5,	17.6)	11.8	(10.2,	13.4)	4.2	(3.0,	5.4)
	Diff.	2.1	(0.1,	4.1)	2.4	(0.4,	4.3)				1.9	(0.2,	3.6)	2.1	(0.3,	3.9)			
Respiratory difficulties	No	14.0	(13.3,	14.7)	10.6	(9.8,	11.4)	3.4	(3.0,	3.8)	18.0	(17.3,	18.7)	13.8	(13.0,	14.6)	4.2	(3.7,	4.6)
	Yes	10.7	(9.6,	11.7)	7.7	(6.5,	8.8)	3.0	(2.4,	3.6)	16.7	(15.4,	18.0)	12.6	(11.1,	14.2)	4.1	(3.3,	4.9)
	Diff.	3.3	(2.1,	4.6)	2.9	(1.6,	4.3)				1.3	(-0.2,	2.7)	1.2	(-0.6,	2.9)			
Stroke[1]	No	13.9	(13.2,	14.5)	10.6	(9.9,	11.3)	3.2	(2.9,	3.6)	18.2	(17.5,	18.8)	14.2	(13.4,	15.0)	4.0	(3.5,	4.4)
	Yes	8.6	(7.3,	10.0)	4.6	(3.0,	6.1)	4.0	(3.1,	5.0)	14.6	(12.9,	16.3)	9.1	(6.9,	11.3)	5.5	(4.3,	6.8)
	Diff.	5.2	(3.7,	6.8)	6.0	(4.3,	7.8)				3.6	(1.8,	5.4)	5.1	(2.8,	7.5)			
Vision impairment	No	13.4	(12.7,	14.0)	10.1	(9.4,	10.9)	3.2	(2.9,	3.6)	17.9	(17.3,	18.6)	13.9	(13.2,	14.7)	4.0	(3.6,	4.4)
	Yes	11.4	(9.8,	12.9)	7.6	(5.8,	9.3)	3.8	(2.8,	4.8)	16.6	(15.1,	18.2)	11.5	(9.6,	13.5)	5.1	(4.1,	6.1)
	Diff.	2.0	(0.3,	3.7)	2.6	(0.7,	4.5)				1.3	(-0.5,	3.0)	2.4	(0.3,	4.5)			
Multiple long-term conditions	No	15.5	(14.5,	16.5)	12.0	(11.0,	13.1)	3.5	(2.9,	4.1)	19.8	(18.8,	20.8)	16.4	(15.3,	17.6)	3.4	(2.7,	4.1)
	Yes	11.4	(10.5,	12.2)	8.0	(7.1,	8.9)	3.4	(2.9,	3.8)	16.1	(15.3,	17.0)	11.4	(10.3,	12.4)	4.8	(4.2,	5.3)
	Diff.	4.1	(2.8,	5.4)	4.0	(2.6,	5.4)				3.7	(2.4,	5.0)	5.0	(3.5,	6.6)			

[1] 1-month step length apart from stroke where model converged at 12-month step

Appendix Table 4: Percentage of remaining years at age 65 spent disability-free (DFLE %) or with disability (DLE %) for men with and without long-term conditions in CFAS I and CFAS II

		CFAS I				CFAS II			
		DFLE %	DFLE % 95% CI	DLE %	DLE % 95% CI	DFLE %	DFLE % 95% CI	DLE %	DLE % 95% CI
Arthritis	No	77.7	(75.8, 79.7)	22.3	(20.3, 24.2)	81.5	(79.8, 83.2)	18.5	(16.8, 20.2)
	Yes	72.0	(69.6, 74.5)	28.0	(25.5, 30.4)	70.7	(68.4, 73.0)	29.3	(27.0, 31.6)
CHD	No	75.8	(74.1, 77.5)	24.2	(22.5, 25.9)	78.1	(76.5, 79.7)	21.9	(20.3, 23.5)
	Yes	72.2	(68.8, 75.7)	27.8	(24.3, 31.2)	72.3	(69.3, 75.3)	27.7	(24.7, 30.7)
Cognitive impairment	No	76.2	(74.3, 78.0)	23.9	(22.0, 25.7)	78.7	(77.1, 80.2)	21.3	(19.8, 22.9)
	Yes	70.3	(67.3, 73.3)	29.7	(26.7, 32.7)	65.0	(61.6, 68.5)	35.0	(31.5, 38.4)
Diabetes	No	75.4	(73.8, 77.0)	24.6	(23.0, 26.2)	77.0	(75.5, 78.6)	23.0	(21.4, 24.5)
	Yes	71.8	(65.7, 77.9)	28.2	(22.1, 34.2)	75.4	(71.9, 78.9)	24.6	(21.1, 28.1)
Hearing difficulties	No	75.6	(73.8, 77.3)	24.4	(22.7, 26.2)	77.5	(75.8, 79.1)	22.5	(20.9, 24.2)
	Yes	73.7	(70.5, 76.9)	26.3	(23.1, 29.5)	74.5	(71.7, 77.2)	25.5	(22.8, 28.3)
PVD	No	75.6	(74.0, 77.2)	24.4	(22.8, 26.0)	77.3	(75.8, 78.8)	22.7	(21.2, 24.2)
	Yes	68.6	(61.6, 75.6)	31.4	(24.4, 38.4)	73.5	(69.2, 77.9)	26.5	(22.1, 30.8)
Respiratory difficulties	No	75.8	(74.1, 77.5)	24.2	(22.5, 25.9)	76.8	(75.3, 78.3)	23.2	(21.7, 24.7)
	Yes	71.9	(68.3, 75.4)	28.1	(24.6, 31.7)	75.6	(72.1, 79.1)	24.4	(20.9, 27.9)
Stroke[1]	No	76.6	(75.1, 78.2)	23.4	(21.8, 24.9)	78.2	(76.7, 79.6)	21.8	(20.4, 23.3)
	Yes	53.1	(47.3, 58.9)	46.9	(41.1, 52.7)	62.2	(56.9, 67.5)	37.8	(32.5, 43.1)
Vision impairment	No	75.8	(74.2, 77.4)	24.2	(22.6, 25.8)	77.8	(76.3, 79.3)	22.2	(20.7, 23.7)
	Yes	66.5	(61.2, 71.8)	33.5	(28.2, 38.8)	69.3	(65.0, 73.7)	30.7	(26.3, 35.0)
Multiple long-term conditions	No	77.6	(75.4, 79.7)	22.4	(20.3, 24.6)	82.8	(81.0, 84.7)	17.2	(15.3, 19.0)
	Yes	70.5	(68.2, 72.7)	29.5	(27.3, 31.8)	70.6	(68.5, 72.6)	29.4	(27.4, 31.5)

[1] 1-month step length apart from stroke where model converged at 12-month step

Appendix Table 5: Total life expectancy, Disability-free life expectancy and life expectancy with disability with 95% confidence intervals (95% CI) at age 65 for women with and without long-term conditions in CFAS I and CFAS II

		CFAS I								CFAS II							
		TLE	TLE 95% CI		DFLE	DFLE 95% CI		DLE	DLE 95% CI		TLE	TLE 95% CI		DFLE	DFLE 95% CI		DLE	DLE 95% CI	
Arthritis	No	16.8	(15.9,	17.6)	10.7	(9.7,	11.7)	6.1	(5.4,	6.7)	19.7	(18.7,	20.8)	13.2	(12.0,	14.4)	6.6	(5.7,	7.4)
	Yes	18.2	(17.4,	18.9)	9.0	(8.3,	9.7)	9.1	(8.4,	9.8)	19.8	(19.0,	20.6)	10.9	(9.9,	11.8)	8.9	(8.1,	9.7)
	Diff.	-1.4	(-2.5,	-0.3)	1.7	(0.5,	2.9)				-0.0	(-1.3,	1.3)	2.3	(0.8,	3.8)			
CHD	No	17.7	(17.1,	18.3)	10.1	(9.5,	10.8)	7.6	(7.0,	8.1)	19.9	(19.1,	20.6)	12.0	(11.2,	12.9)	7.8	(7.2,	8.4)
	Yes	16.1	(14.5,	17.7)	6.9	(5.8,	8.1)	9.2	(7.7,	10.6)	17.4	(15.3,	19.5)	9.3	(7.7,	10.8)	8.1	(6.5,	9.7)
	Diff.	1.6	(-0.1,	3.3)	3.2	(1.9,	4.5)				2.5	(0.2,	4.7)	2.8	(1.0,	4.6)			
Cognitive impairment	No	18.8	(18.0,	19.5)	10.4	(9.7,	11.1)	8.4	(7.7,	9.1)	20.5	(19.7,	21.3)	12.7	(11.8,	13.5)	7.8	(7.2,	8.5)
	Yes	16.0	(15.1,	16.9)	8.4	(7.4,	9.4)	7.6	(6.8,	8.4)	17.4	(16.1,	18.7)	8.4	(7.0,	9.8)	8.9	(7.8,	10.1)
	Diff.	2.7	(1.5,	3.9)	2.0	(0.7,	3.2)				3.1	(1.6,	4.7)	4.2	(2.6,	5.9)			
Diabetes	No	17.8	(17.1,	18.4)	10.0	(9.4,	10.7)	7.7	(7.2,	8.2)	20.0	(19.3,	20.7)	12.2	(11.4,	13.0)	7.8	(7.2,	8.4)
	Yes	14.8	(12.9,	16.8)	5.8	(4.0,	7.6)	9.0	(7.0,	11.1)	17.3	(15.5,	19.2)	8.5	(6.9,	10.1)	8.8	(7.2,	10.4)
	Diff.	2.9	(0.8,	5.0)	4.2	(2.3,	6.1)				2.6	(0.7,	4.6)	3.7	(1.9,	5.5)			
Hearing difficulties	No	17.5	(16.8,	18.1)	9.8	(9.2,	10.5)	7.6	(7.1,	8.2)	19.8	(19.1,	20.6)	11.9	(11.1,	12.7)	7.9	(7.3,	8.6)
	Yes	17.9	(16.7,	19.1)	9.4	(8.1,	10.7)	8.5	(7.4,	9.7)	18.9	(17.4,	20.4)	10.9	(9.3,	12.4)	8.0	(6.8,	9.2)
	Diff.	-0.4	(-1.8,	0.9)	0.5	(-1.0,	1.9)				1.0	(-0.7,	2.7)	1.0	(-0.7,	2.8)			
PVD	No	17.6	(17.0,	18.2)	9.8	(9.2,	10.5)	7.8	(7.2,	8.3)	19.6	(18.9,	20.3)	12.0	(11.2,	12.8)	7.7	(7.1,	8.2)
	Yes	17.6	(14.4,	20.8)	7.8	(5.7,	9.9)	9.8	(6.8,	12.9)	19.5	(17.0,	22.0)	9.3	(7.3,	11.4)	10.1	(8.0,	12.3)
	Diff.	0.0	(-3.3,	3.3)	2.1	(-0.1,	4.3)				0.2	(-2.4,	2.8)	2.6	(0.4,	4.8)			
Respiratory difficulties	No	17.8	(17.1,	18.4)	10.3	(9.6,	10.9)	7.5	(7.0,	8.1)	20.1	(19.3,	20.8)	12.4	(11.6,	13.2)	7.7	(7.1,	8.3)
	Yes	16.9	(15.7,	18.0)	8.0	(6.9,	9.1)	8.9	(7.8,	10.0)	17.9	(16.5,	19.3)	9.6	(8.2,	10.9)	8.3	(7.1,	9.5)
	Diff.	0.9	(-0.4,	2.3)	2.3	(1.0,	3.6)				2.2	(0.6,	3.8)	2.8	(1.2,	4.4)			
Stroke	No	18.1	(17.5,	18.7)	10.1	(9.5,	10.8)	8.0	(7.4,	8.5)	20.0	(19.3,	20.6)	12.0	(11.2,	12.8)	8.0	(7.4,	8.6)
	Yes	13.3	(11.7,	14.8)	5.4	(3.6,	7.3)	7.8	(6.4,	9.3)	17.3	(14.8,	19.8)	8.9	(6.5,	11.3)	8.4	(6.1,	10.6)

	Diff.	4.8	(3.1,	6.5)	4.7	(2.8,	6.7)				2.7	(0.1,	5.2)	3.0	(0.5,	5.6)			
Vision	No	17.6	(16.9,	18.2)	9.9	(9.2,	10.6)	7.7	(7.1,	8.2)	19.9	(19.1,	20.6)	12.1	(11.2,	12.9)	7.8	(7.2,	8.4)
impairment	Yes	16.5	(14.8,	18.2)	8.1	(6.8,	9.4)	8.5	(7.0,	10.0)	18.2	(16.5,	19.9)	9.7	(8.0,	11.3)	8.6	(7.1,	10.0)
	Diff.	1.0	(-0.8,	2.8)	1.8	(0.4,	3.3)				1.6	(-0.2,	3.5)	2.4	(0.6,	4.2)			
Multiple	No	19.2	(18.2,	20.1)	11.7	(10.7,	12.6)	7.5	(6.7,	8.4)	22.5	(21.3,	23.6)	14.8	(13.7,	16.0)	7.7	(6.7,	8.6)
long-term	Yes	16.5	(15.8,	17.3)	8.1	(7.3,	8.9)	8.5	(7.7,	9.2)	18.1	(17.2,	19.0)	9.4	(8.4,	10.4)	8.7	(7.8,	9.5)
Conditions	Diff.	2.6	(1.4,	3.8)	3.6	(2.3,	4.8)				4.4	(2.9,	5.9)	5.4	(3.9,	7.0)			

Appendix Table 6: Percentage of remaining years at age 65 spent disability-free (DFLE %) or with disability (DLE %) for women with and without long-term conditions in CFAS I and CFAS II

		CFAS I						CFAS II					
		DFLE %	DFLE % 95% CI		DLE %	DLE % 95% CI		DFLE %	DFLE % 95% CI		DLE %	DLE % 95% CI	
Arthritis	No	63.8	(61.7,	66.0)	36.2	(34.0,	38.3)	66.8	(64.5,	69.1)	33.2	(30.9,	35.5)
	Yes	49.7	(47.8,	51.6)	50.3	(48.4,	52.2)	54.9	(53.0,	56.8)	45.1	(43.2,	47.0)
CHD	No	57.3	(55.7,	58.9)	42.7	(41.1,	44.3)	60.6	(59.0,	62.3)	39.4	(37.7,	41.0)
	Yes	43.0	(39.3,	46.8)	57.0	(53.2,	60.7)	53.2	(49.4,	57.0)	46.8	(43.0,	50.6)
Cognitive impairment	No	55.4	(53.5,	57.3)	44.6	(42.7,	46.5)	61.8	(60.0,	63.5)	38.2	(36.5,	40.0)
	Yes	52.5	(50.2,	54.7)	47.5	(45.3,	49.8)	48.5	(45.6,	51.4)	51.5	(48.6,	54.4)
Diabetes	No	56.5	(55.1,	58.0)	43.5	(42.0,	44.9)	61.1	(59.6,	62.7)	38.9	(37.3,	40.4)
	Yes	39.2	(33.3,	45.1)	60.8	(54.9,	66.7)	49.3	(44.9,	53.7)	50.7	(46.3,	55.1)
Hearing difficulties	No	56.3	(54.7,	57.9)	43.7	(42.1,	45.3)	60.1	(58.4,	61.7)	39.9	(38.3,	41.6)
	Yes	52.3	(49.1,	55.5)	47.7	(44.5,	50.9)	57.8	(54.7,	60.8)	42.2	(39.2,	45.3)
PVD	No	55.9	(54.4,	57.3)	44.1	(42.6,	45.6)	61.0	(59.4,	62.6)	39.0	(37.4,	40.6)
	Yes	44.1	(36.2,	52.0)	55.9	(48.0,	63.8)	48.0	(43.1,	53.0)	52.0	(47.0,	56.9)
Respiratory difficulties	No	57.7	(56.1,	59.3)	42.3	(40.7,	43.9)	61.6	(60.0,	63.3)	38.4	(36.7,	40.0)
	Yes	47.4	(44.0,	50.8)	52.6	(49.2,	56.0)	53.6	(50.4,	56.9)	46.4	(43.1,	49.6)
Stroke[1]	No	56.0	(54.5,	57.5)	44.0	(42.5,	45.5)	60.0	(58.4,	61.5)	40.0	(38.5,	41.6)
	Yes	40.9	(35.5,	46.3)	59.1	(53.7,	64.5)	51.7	(46.2,	57.2)	48.3	(42.8,	53.8)

Vision impairment	No	56.4	(54.9,	58.0)	43.6	(42.0,	45.1)	60.7	(59.1,	62.3)	39.3	(37.7,	40.9)
	Yes	48.8	(45.1,	52.5)	51.2	(47.5,	54.9)	53.0	(49.2,	56.8)	47.0	(43.2,	50.8)
Multiple long-term conditions	No	60.8	(58.7,	62.9)	39.2	(37.1,	41.3)	66.0	(63.8,	68.2)	34.0	(31.8,	36.2)
	Yes	48.9	(47.0,	50.8)	51.1	(49.2,	53.0)	52.1	(50.1,	54.1)	47.9	(45.9,	49.9)

[1] 1-month step length apart from stroke where model converged at 12-month step

Appendix Table 7: Relative Risk Ratio (RRR) of transitioning between disability states in CFAS II (2008) compared to CFAS I (1991) for men and women with each long-term condition, 95% confidence interval (CI) in parentheses. Shaded grey if confidence intervals do not include one.

		Men			Women		
		RRR	95% CI		RRR	95% CI	
Arthritis	No disability -> Disability	0.9	(0.7,	1.2)	0.7	(0.6,	0.8)
	No disability -> Death	0.5	(0.3,	0.8)	0.5	(0.2,	1.1)
	Disability -> No disability	1.2	(0.7,	1.8)	1.0	(0.7,	1.3)
	Disability -> Death	0.7	(0.6,	0.9)	1.0	(0.9,	1.2)
CHD	No disability -> Disability	0.7	(0.5,	0.9)	0.6	(0.4,	0.8)
	No disability -> Death	0.4	(0.2,	0.7)	0.8	(0.2,	2.5)
	Disability -> No disability	0.7	(0.4,	1.3)	1.0	(0.6,	1.7)
	Disability -> Death	0.7	(0.5,	0.9)	0.9	(0.7,	1.1)
Cognitive impairment	No disability -> Disability	1.0	(0.7,	1.5)	0.9	(0.7,	1.1)
	No disability -> Death	0.4	(0.2,	0.9)	0.6	(0.2,	1.7)
	Disability -> No disability	1.4	(0.7,	3.0)	0.9	(0.6,	1.5)
	Disability -> Death	0.8	(0.7,	1.0)	0.9	(0.8,	1.1)
Diabetes	No disability -> Disability	0.7	(0.4,	1.3)	0.7	(0.4,	1.1)
	No disability -> Death	0.5	(0.2,	1.1)	0.6	(0.1,	3.3)
	Disability -> No disability	1.3	(0.5,	3.8)	1.9	(0.5,	6.5)
	Disability -> Death	0.7	(0.5,	1.1)	0.9	(0.6,	1.2)
Hearing difficulties	No disability -> Disability	0.8	(0.5,	1.1)	0.7	(0.5,	0.9)
	No disability -> Death	0.4	(0.2,	0.8)	0.8	(0.3,	2.2)
	Disability -> No disability	1.1	(0.6,	2.1)	1.0	(0.6,	1.7)
	Disability -> Death	0.8	(0.7,	1.1)	1.1	(0.9,	1.3)
PVD[1]	No disability -> Disability	0.7	(0.3,	1.3)	0.6	(0.3,	1.3)
	No disability -> Death	0.7	(0.3,	1.4)	0.2	(0.0,	2.3)
	Disability -> No disability	1.7	(0.4,	7.2)	0.6	(0.2,	1.7)

	Disability -> Death	0.6	(0.4,	1.0)	0.5	(0.3,	0.8)
Respiratory difficulties	No disability -> Disability	0.7	(0.5,	1.1)	0.7	(0.5,	0.9)
	No disability -> Death	0.2	(0.1,	0.6)	1.0	(0.3,	3.3)
	Disability -> No disability	1.8	(0.9,	3.5)	0.9	(0.5,	1.4)
	Disability -> Death	0.8	(0.7,	1.1)	0.9	(0.8,	1.2)
Stroke[1]	No disability -> Disability	0.5	(0.2,	1.0)	0.6	(0.3,	1.3)
	No disability -> Death	0.3	(0.1,	1.0)	0.5	(0.1,	2.4)
	Disability -> No disability	1.3	(0.5,	3.5)	2.8	(1.0,	7.5)
	Disability -> Death	0.6	(0.5,	0.9)	0.8	(0.6,	1.0)
Vision impairment	No disability -> Disability	0.7	(0.4,	1.1)	0.6	(0.4,	0.9)
	No disability -> Death	0.2	(0.1,	0.8)	0.4	(0.1,	1.9)
	Disability -> No disability	0.9	(0.3,	2.5)	0.8	(0.5,	1.5)
	Disability -> Death	0.8	(0.6,	1.1)	1.0	(0.9,	1.3)
Multiple long-term conditions	No disability -> Disability	0.8	(0.6,	1.0)	0.7	(0.6,	0.8)
	No disability -> Death	0.5	(0.3,	0.7)	0.5	(0.2,	1.1)
	Disability -> No disability	1.2	(0.8,	1.8)	1.0	(0.7,	1.3)
	Disability -> Death	0.7	(0.6,	0.9)	1.0	(0.9,	1.2)

[1]Models converged at 3-month steps apart from PVD and stroke models which converged at 12-month steps

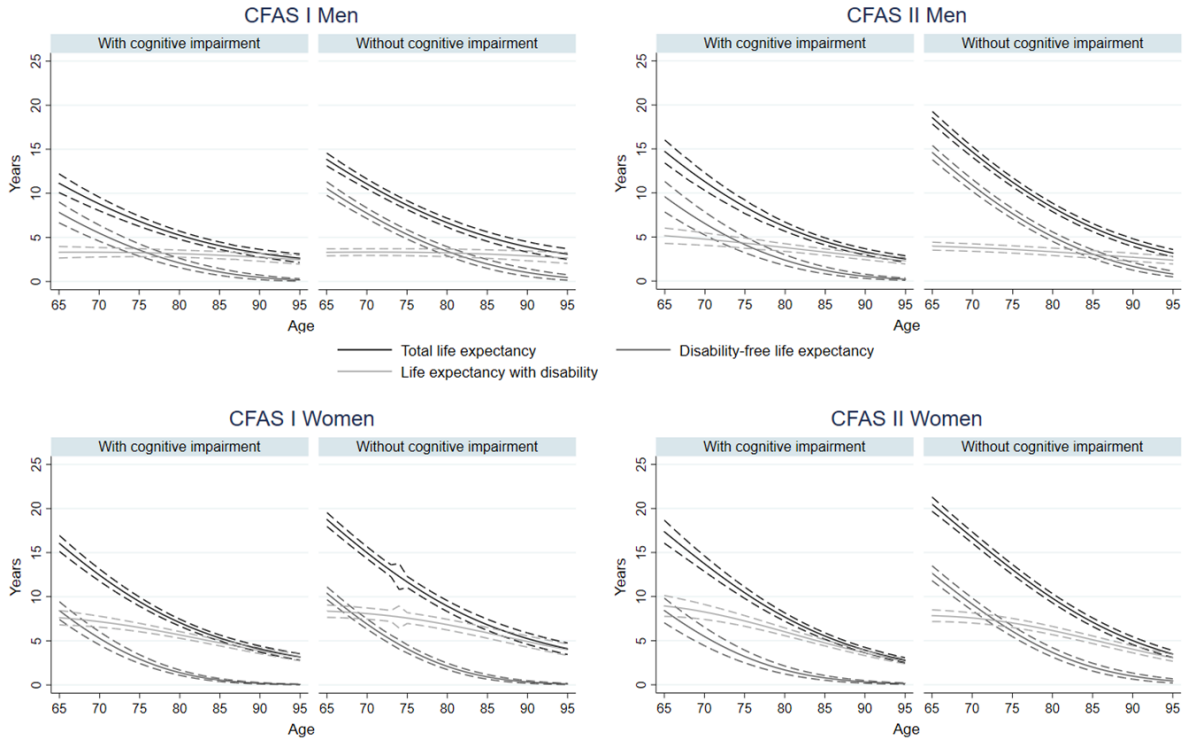
Appendix Table 8: Relative Risk Ratios (RRR) for transition with each long-term condition (relative to without condition) from unadjusted models for men and women in CFAS I and CFAS II (numbers in italics where confidence intervals do not include one).

		Men						Women					
		CFAS I			CFAS II			CFAS I			CFAS II		
		RRR	95% CI		RRR	95% CI		RRR	95% CI		RRR	95% CI	
Arthritis	No disability -> Disability	1.2	(0.9,	1.5)	*1.6*	*(1.2,*	*2.1)*	*1.8*	*(1.5,*	*2.2)*	*1.6*	*(1.3,*	*2.1)*
	No disability -> Death	1.0	(0.7,	1.4)	1.0	(0.6,	1.7)	0.7	(0.4,	1.4)	0.5	(0.2,	1.3)
	Disability -> No disability	1.0	(0.6,	1.6)	0.9	(0.7,	1.4)	1.4	(0.9,	2.2)	0.9	(0.7,	1.3)
	Disability -> Death	0.8	(0.7,	1.0)	*0.7*	*(0.6,*	*0.9)*	*0.7*	*(0.6,*	*0.8)*	0.9	(0.8,	1.0)
CHD	No disability -> Disability	*1.8*	*(1.3,*	*2.4)*	*1.5*	*(1.1,*	*2.0)*	*2.0*	*(1.5,*	*2.6)*	*1.5*	*(1.1,*	*2.0)*
	No disability -> Death	*1.6*	*(1.1,*	*2.4)*	1.1	(0.6,	1.9)	*2.6*	*(1.2,*	*5.8)*	*3.0*	*(1.4,*	*6.6)*
	Disability -> No disability	*1.8*	*(1.1,*	*3.0)*	1.0	(0.7,	1.5)	1.2	(0.8,	1.8)	1.1	(0.8,	1.6)
	Disability -> Death	1.1	(0.9,	1.3)	1.0	(0.8,	1.2)	*0.8*	*(0.7,*	*0.9)*	0.9	(0.8,	1.0)
Cognitive impairment	No disability -> Disability	1.3	(1.0,	1.8)	*1.9*	*(1.4,*	*2.6)*	1.2	(1.0,	1.5)	*1.5*	*(1.2,*	*2.0)*
	No disability -> Death	1.4	(1.0,	1.9)	0.8	(0.3,	2.1)	1.1	(0.7,	1.8)	1.0	(0.3,	3.1)
	Disability -> No disability	*0.5*	*(0.3,*	*0.8)*	*0.5*	*(0.3,*	*0.7)*	0.7	(0.5,	1.0)	*0.6*	*(0.4,*	*0.8)*
	Disability -> Death	1.1	(0.9,	1.3)	1.2	(1.0,	1.4)	*1.4*	*(1.2,*	*1.6)*	*1.2*	*(1.1,*	*1.4)*
Diabetes	No disability -> Disability	1.4	(0.9,	2.3)	1.3	(0.9,	1.9)	*1.6*	*(1.1,*	*2.3)*	*1.6*	*(1.2,*	*2.2)*
	No disability -> Death	1.6	(0.8,	3.1)	1.6	(0.9,	2.8)	*2.9*	*(1.1,*	*7.7)*	1.4	(0.4,	5.1)
	Disability -> No disability	0.9	(0.4,	2.2)	1.0	(0.7,	1.5)	0.5	(0.2,	1.1)	0.8	(0.5,	1.2)
	Disability -> Death	1.1	(0.8,	1.5)	1.2	(1.0,	1.5)	0.9	(0.7,	1.2)	1.1	(0.9,	1.3)
Hearing difficulties	No disability -> Disability	1.3	(1.0,	1.8)	*1.4*	*(1.1,*	*1.9)*	1.1	(0.9,	1.4)	1.0	(0.8,	1.3)
	No disability -> Death	0.8	(0.5,	1.4)	0.6	(0.3,	1.2)	0.8	(0.3,	2.3)	1.1	(0.5,	2.9)
	Disability -> No disability	1.3	(0.7,	2.3)	1.1	(0.8,	1.7)	0.9	(0.6,	1.5)	0.8	(0.6,	1.1)
	Disability -> Death	1.1	(0.9,	1.3)	1.2	(1.0,	1.4)	0.9	(0.8,	1.1)	1.1	(0.9,	1.2)
PVD	No disability -> Disability	1.5	(1.0,	2.4)	1.3	(0.9,	2.0)	*1.8*	*(1.1,*	*3.1)*	1.3	(0.9,	1.9)
	No disability -> Death	1.6	(0.8,	3.0)	1.9	(1.0,	3.5)	2.4	(0.6,	9.8)	1.4	(0.4,	5.8)
	Disability -> No disability	1.1	(0.5,	2.5)	1.1	(0.7,	1.7)	1.5	(0.8,	2.9)	0.7	(0.5,	1.1)
	Disability -> Death	0.9	(0.7,	1.3)	0.9	(0.7,	1.1)	*0.7*	*(0.5,*	*0.9)*	*0.8*	*(0.6,*	*0.9)*
Respiratory difficulties	No disability -> Disability	*1.4*	*(1.1,*	*1.9)*	1.4	(1.0,	2.0)	*1.5*	*(1.2,*	*1.9)*	1.3	(1.0,	1.7)
	No disability -> Death	*1.6*	*(1.1,*	*2.4)*	0.6	(0.2,	1.7)	1.0	(0.4,	2.5)	1.6	(0.7,	3.7)
	Disability -> No disability	0.7	(0.4,	1.3)	1.2	(0.8,	1.8)	0.9	(0.6,	1.3)	0.7	(0.5,	1.0)

	Disability -> Death	1.2	(1.0,	1.5)	*1.4*	*(1.1,*	*1.7)*	0.9	(0.8,	1.1)	1.1	(0.9,	1.2)
Stroke[1]	No disability -> Disability	*3.6*	*(2.3,*	*5.6)*	*2.2*	*(1.4,*	*3.5)*	*2.0*	*(1.3,*	*3.1)*	*1.7*	*(1.0,*	*3.0)*
	No disability -> Death	1.5	(0.7,	3.2)	1.3	(0.6,	2.6)	1.7	(0.6,	4.6)	1.6	(0.4,	7.0)
	Disability -> No disability	0.5	(0.2,	1.0)	*0.5*	*(0.3,*	*0.9)*	*0.5*	*(0.3,*	*0.9)*	1.0	(0.7,	1.6)
	Disability -> Death	1.3	(1.0,	1.6)	1.0	(0.8,	1.3)	*1.5*	*(1.2,*	*1.8)*	1.2	(1.0,	1.5)
Vision impairment	No disability -> Disability	*1.6*	*(1.1,*	*2.3)*	1.4	(1.0,	1.9)	*1.5*	*(1.2,*	*2.0)*	1.3	(1.0,	1.8)
	No disability -> Death	1.1	(0.5,	2.1)	0.4	(0.1,	1.3)	1.9	(0.8,	4.8)	1.3	(0.4,	3.9)
	Disability -> No disability	0.7	(0.3,	1.5)	0.5	(0.3,	1.0)	1.2	(0.8,	1.9)	0.8	(0.5,	1.3)
	Disability -> Death	1.0	(0.8,	1.3)	1.1	(0.9,	1.3)	0.9	(0.8,	1.0)	1.0	(0.9,	1.2)
Multiple long-term conditions	No disability -> Disability	*1.9*	*(1.4,*	*2.4)*	*2.4*	*(1.7,*	*3.2)*	*1.7*	*(1.4,*	*2.0)*	*1.7*	*(1.3,*	*2.1)*
	No disability -> Death	1.3	(0.9,	1.8)	1.0	(0.6,	1.6)	0.8	(0.4,	1.7)	1.1	(0.5,	2.3)
	Disability -> No disability	0.7	(0.4,	1.3)	0.8	(0.5,	1.3)	0.7	(0.5,	1.1)	*0.5*	*(0.4,*	*0.7)*
	Disability -> Death	*1.4*	*(1.1,*	*1.7)*	1.2	(0.9,	1.4)	1.2	(1.0,	1.4)	*1.4*	*(1.1,*	*1.7)*

[1] 1-month step length apart from stroke where model converged at 12-month step

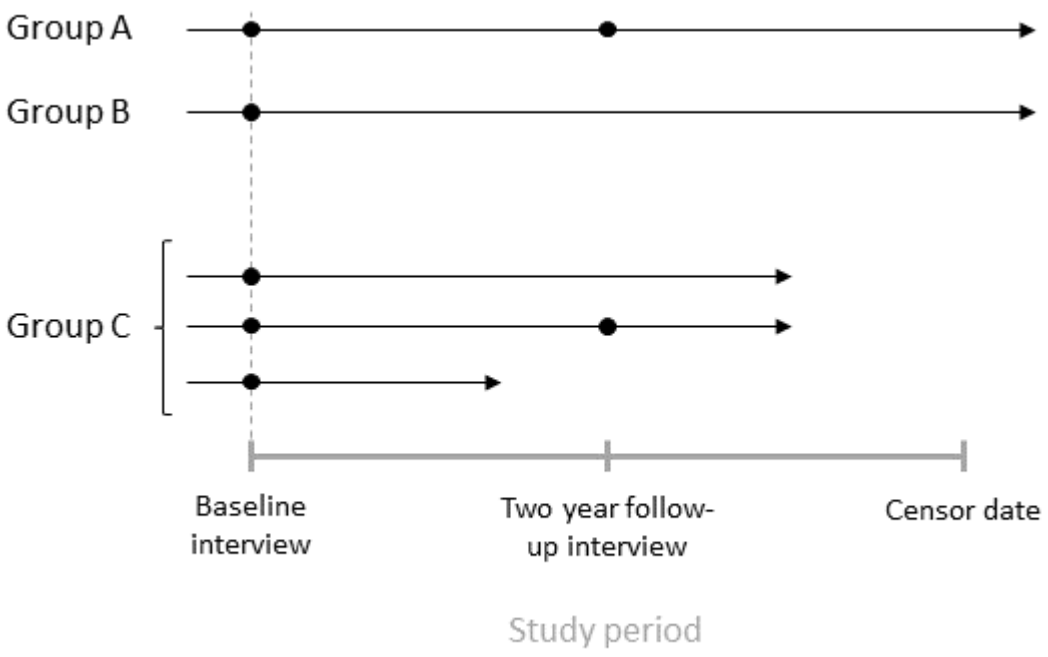
Appendix Figure 1: Total life expectancy, disability-free life expectancy and life expectancy with disability over ages 65 to 95 years for men and women in CFAS I and CFAS II with and without cognitive impairment



Inverse probability weighting for life expectancies

Inverse probability weighting was used for the life expectancy analysis to ensure population representativeness. Here the weights used for the life expectancy analysis are described. The weighting differs to the weighting used for the PAF models as those who died were included in the life expectancy models but not in the PAF models. Anyone who was still alive by the censor date and who participated in baseline and the two-year follow up interview (Group A, Appendix Figure 2) were baseline weighted and also longitudinally weighted. The longitudinal weights were based on age, sex, centre, deprivation, education, social class, cognitive function, disability, number of long-term conditions (count, not percentage as in the MLTC variable), self-rated health and smoking. The longitudinal weights compared Group A (Appendix Figure 2) to Group B (Appendix Figure 2) as the reference category. Anyone who was alive by the censor date but only participated in the baseline interview (Group B, Appendix Figure 2) made no recorded transitions and were then excluded from the life expectancy models. Anyone who died before the censoring date (two years after the two-year follow-up interview) (Group C, Appendix Figure 2) were baseline weighted for age, sex, deprivation and care home status.

Appendix Figure 2: Possible routes from baseline through study period for a participant (arrow head indicates death)



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