Office for National Statistics

Proposed method changes to UK health state life expectancies

This report assesses three methods for future estimation of health state life expectancies and is consulting on these methods

Contact:
Chris White
chris.white@ons.gsi.gov.uk
+44 (0)1633 455865

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Table of contents

1 . Main points

- This technical report assesses three options for reducing random variation in the local area health state life expectancies published by the Office for National Statistics (ONS), which adjusts self-reported health prevalence rates using a least squares regression method including a quadratic explanatory age variable; data from the Annual Population Survey (APS) and the 2011 Census were combined in the methods.
- The purpose is to reduce the propensity for sharp deviations in health state life expectancies over time in some local areas and improve the plausibility of trajectories.
- It was found that the mid-point of an age-band together with its square and the self-reported health prevalence at the 2011 Census were good estimators of age-specific self-reported health states across most local areas, improving the capture of the relationship between health and age found in the 2011 Census data and elsewhere.
- The modelled estimates conformed to a smoother, more plausible distribution of health state prevalence with increasing age, largely eliminating the sharp irregular deviations between adjacent age groupings found in some areas using observed APS data.
- Healthy life expectancy (HLE) estimates calculated using the proposed method had greater correspondence to those based on the 2011 Census than HLE calculated using observed APS prevalence, when taking account of all local areas in the UK for all ages; this was most notably observed in HLE estimates at age 65, where the proposed method yields estimates closer to the 2011 Census than those published for England and using the existing method for Scotland and Wales.
- The effect of the proposed method on age-specific HLE across local areas was less than that observed for health state prevalence; this partly arises from the averaging out of the volatile prevalence estimates found using published data, but mostly from the life expectancy component that remains unchanged.
- Generally the proposed method yields a similar direction of change to the published estimates when comparing non-overlapping time periods for most local areas.

A consultation is being run alongside this report to gain feedback from users on the proposed changes to guide decisions on the merit of implementing this method change. We welcome responses to the consultation within the next eight weeks from time of publication. A hard copy of the consultation questions is available together with an online version. The consultation will close on 8 February 2018.

2 . Things you need to know about this release

The adjusted R squared term: Similar to the R squared term, the adjusted R squared term measures the explanatory power of a regression model by measuring how well the data points fit a curve of best fit, taking account of the number of explanatory variables included in the model. It can range from 0 to 1 where 0 represents no explanatory power and 1 total explanatory power. The adjusted R squared can sometimes be negative, if the model contains explanatory variables that have a very weak association with the outcome variable. In general, the closer an adjusted R squared value is to 1, the more explanatory power the model has.

Imputation method: The Annual Population Survey does not collect data for individuals under the age of 16 and sparsely in some local areas for those aged 85 and over. For estimates of healthy life expectancy (HLE) at birth, the “Good” health prevalence for children is estimated using the 16 to 19 health state prevalence rate, which is adjusted using a factor that follows the pattern of change from this age to younger ages found in 2011 Census data. A similar approach is used for the 80 to 84 age-band to older ages.

The 2011 Census is considered a robust estimate of self-reported health prevalence, as non-response is low and it aims to cover the entire population. The 2011 Census is therefore a useful source to inform the imputation of health state prevalence for missing or sparsely-sampled older age groups. For more details of the imputation method please see the Method changes to life and health state expectancies.

Health state life expectancies are based on subjective self-reporting using survey questions. HLE is calculated from self-reported health status derived from the following survey question:

“How is your health in general; would you say it was...”

Very good; Good; Fair; Bad; Very bad

Respondents answering “Very good” or “Good” were classified as in good general health and thereby “healthy” for the purposes of the HLE metric.

Disability-free life expectancy (DFLE) is calculated from self-reported disability status also from the APS questions. The disability questions collected between 2010 to 2012 and 2013 to 2015 were different.

In 2010 to 2012, respondents were asked:

“Do you have any health problems or disabilities that you expect will last for more than a year?”

Yes; No

And if “Yes” respondents were then asked:

“Do these health problems or disabilities, when taken singly or together, substantially limit your ability to carry out normal day-to-day activities?”

Yes; No

From April 2013, and therefore for the majority of the 2013 to 2015 estimates the respondents were asked:

“Do you have any physical or mental health conditions or illnesses lasting or expected to last 12 months or more?”

Yes; No

And if “Yes” respondents were then asked:

“Does your condition or illness/do any of your conditions or illnesses reduce your ability to carry out day-to-day activities?”

Yes, a lot; Yes, a little; No

The questions classifying individuals to disability status were changed in April 2013 following a review into how disability should be measured in national surveys. Primary harmonised standards for disability data collection and the production of statistical measures of disability (PDF, 136KB) are available. The survey data used in the disability-free life expectancy datasets is predominantly based on the questions asked since April 2013, which classified someone as having a disability if they answered “Yes” to having a physical or mental health condition lasting a year or more and answered “Yes, a lot” or “Yes, a little” to the follow-up question on activity restriction.

One important difference between these questions is that since 2013, mental as well as physical conditions are explicitly mentioned, designed to improve the capture of mental health conditions and illness. Due to this change, the change in the introductory paragraph of the disability section being re-worded in 2010, and the fact that extent of disability is now captured, there has been a difference in the number of people reporting disabilities. Therefore, estimates on either side of the discontinuity (before and after April 2013) should not be directly compared. This report does not comment on the modelling of disability prevalence but the modelled estimates for the 2013 to 2015 period are available in the datasets.

3 . Introduction

Estimates of healthy life expectancy (HLE) and disability-free life expectancy (DFLE) at both the national and subnational level are currently calculated using the Annual Population Survey (APS). We have been using this source to estimate health state life expectancies; for HLE the period commencing 2009 to 2011 extending to 2014 to 2016 and for DFLE the period commencing 2006 to 2008. Stakeholders have wanted estimates of these summary measures of population health at a subnational level, but such estimates depend on survey data with large enough samples across subnational geographies.

The APS is a large population survey with a UK sample merged over three years of approximately 450,000 unique records. It is designed primarily to describe and analyse labour market outcomes at a local level. The sample sizes, particularly in older age groups for some subnational populations are small and therefore vulnerable to sharp random variation in age-specific self-reported health state prevalence. The APS-based prevalence of self-reported health states in areas with the smallest populations can be erratic across age strata, not declining with age in a smooth curve, as is found in population census data and in accordance with a typically observed decline in health status with increasing age from adulthood.

We have tested a proposed method, designed to address the current weakness of small sample sizes producing somewhat erratic health state prevalence estimates across the age distribution in those areas with smaller populations. The method applies a least squares regression to estimate the prevalence rates with a quadratic line of best fit.

This report describes the results of three variants that were investigated to improve the calculation of HLE and recommends a preferred method, which we propose to use to calculate future health state life expectancies (including DFLE) and revise the back series. The method would also apply to the future measurement of inequality in health state life expectancy based on area deprivation. The three variants and the impact of adopting our proposed method are discussed in more detail. A consultation is being run alongside this report to gain feedback from users on the proposed changes before a decision is taken to implement the proposed method change. We welcome responses to the consultation within the next eight weeks.

Although the proposed change is relevant for both HLE and DFLE, this report limits its focus to HLE. Estimates for DFLE for the period 2013 to 2015 can be found in the accompanying datasets. DFLE was not tested to the same extent because of differences between data items asked at census and in the APS and the change of items used to classify individuals to disability status changing in 2013 making trajectory analyses problematic.

4 . Background

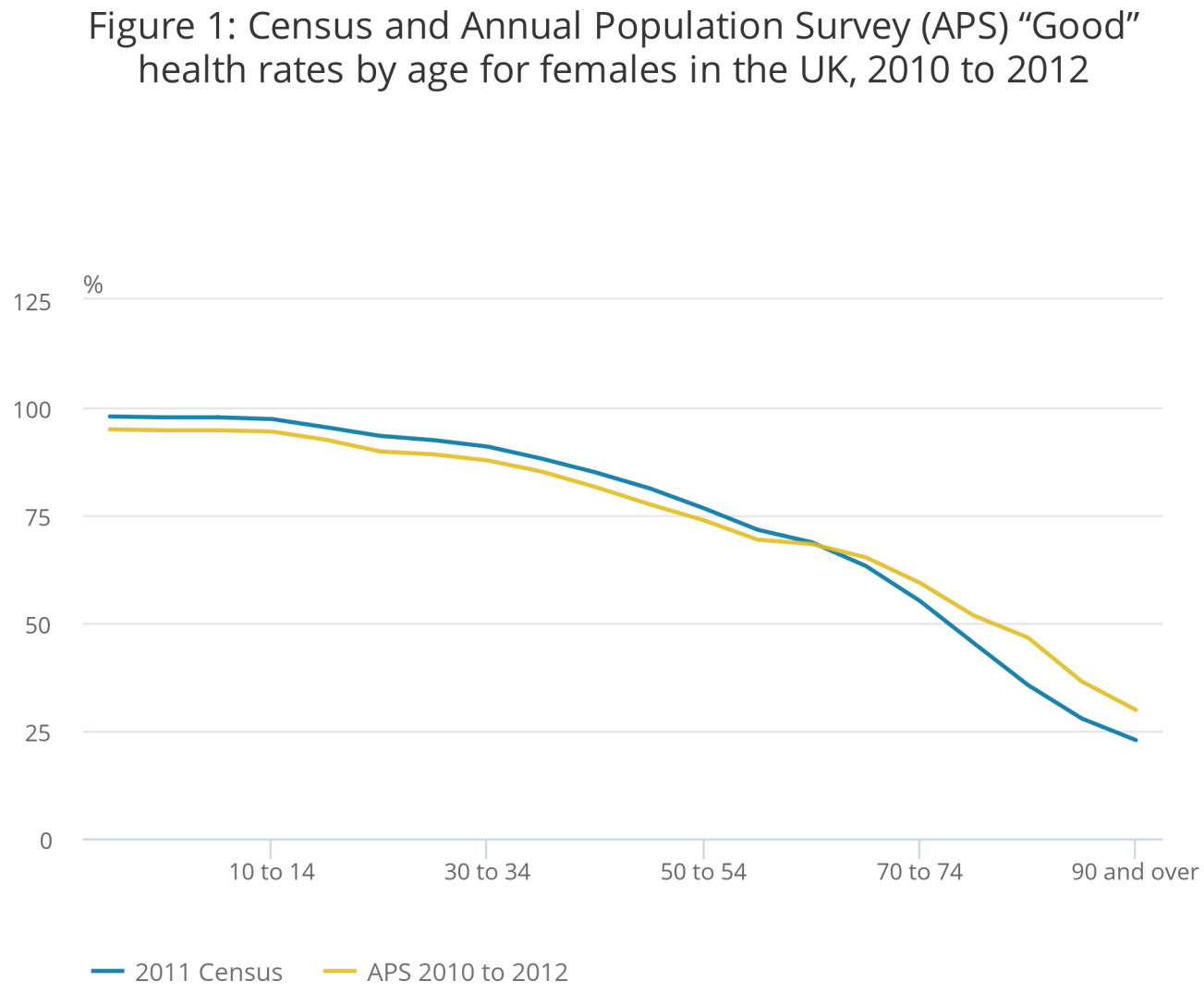
In 2016, we extended subnational reporting of health state life expectancy to local areas in the UK. Local areas here refer to the 150 upper tier local authorities in England, the 22 unitary authorities in Wales, the 32 council areas in Scotland and the 11 local government districts in Northern Ireland. This occurred at a time when subnational life table methodology changed from an abridged life table closed at ages 85 and over to one closed at ages 90 and over.

A methods paper was published in November 2016 to explain plans to impute health prevalence at both younger age groups (under 16) and in those aged 85 to 89 and 90 and over using 2011 Census data to enable consistency in life expectancy and health state life expectancy life tables. The new imputation method explicitly used the 2011 Census data to understand the transition in health status from those aged 16 to 19 to those age groups where data are not collected (those aged 0 to 15) and from those aged 80 to 84 to those where data are sparse (ages 85 to 89 and 90 and over).

Since then we have conducted further work to compare self-reported general health and its transition with increasing age using the 2011 Census and the Annual Population Survey. We have explored ways to combine these sources to improve estimation of health status and its transition across the age distribution, particularly for local areas.

As the census covers the entire UK population, it gives the most representative, reliable and accurate health and disability-free prevalence rates. These rates calculated from a census also conform to a plausible distribution of health status decreasing smoothly with age and at a faster rate of decrease post-traditional retirement ages. At the UK level, this relationship is also found using published APS data as shown in Figure 1 and is currently used to calculate healthy life expectancy (HLE) and disability-free life expectancy (DFLE).

Figure 1: Census and Annual Population Survey (APS) "Good" health rates by age for females in the UK, 2010 to 2012



Source: 2011 Census; Annual Population Survey 2010 to 2012

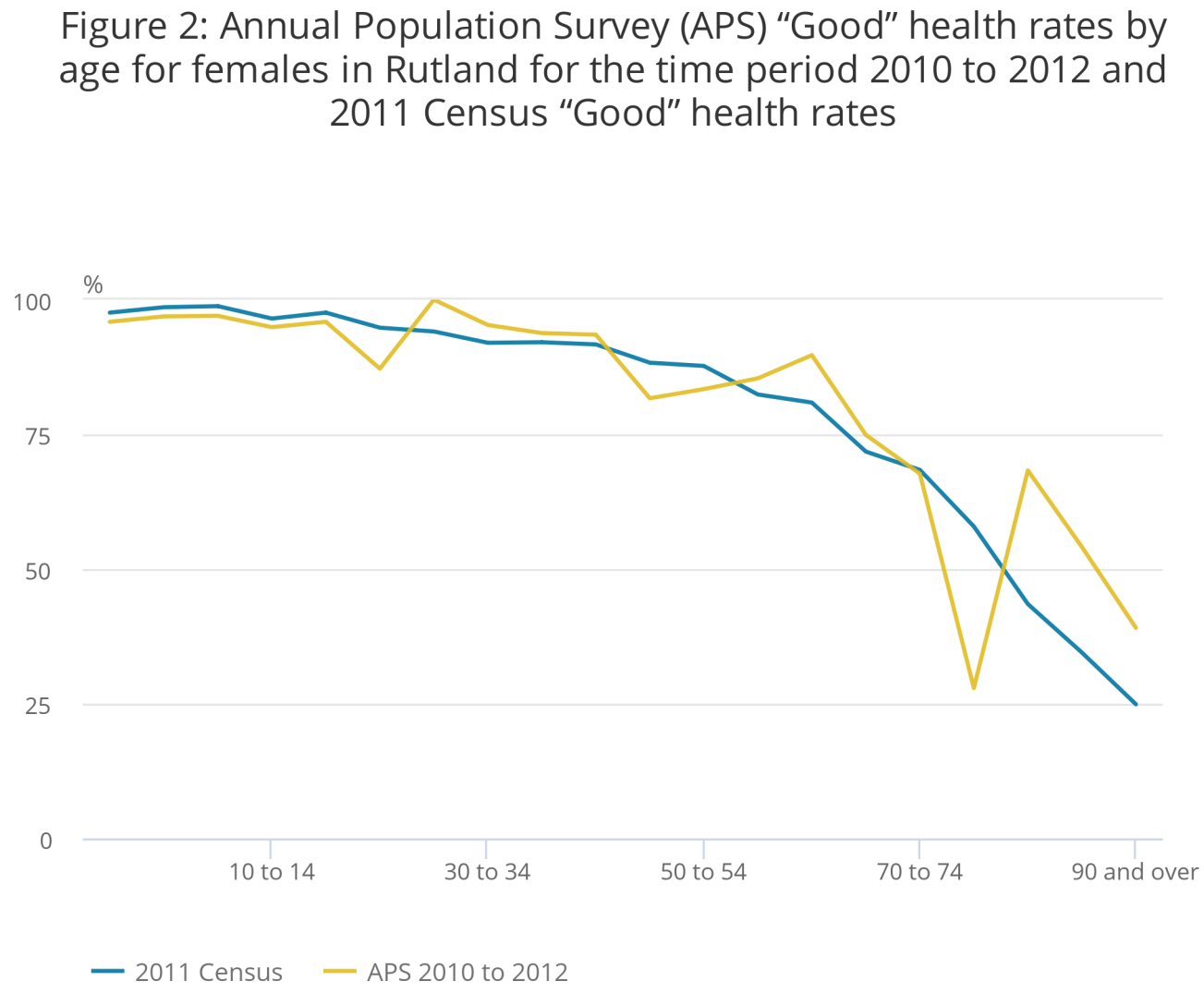
Notes:

1. Applies imputation for ages 14 and below and 85 and above.

The APS estimates of "Good" general health were below those from the 2011 Census in ages under 60 and above those from the 2011 Census at ages 65 and over. As the APS collects data through a combination of face-to-face interviews and telephone interviews, a sampling selection effect may be at work whereby a higher proportion of those with not good health are available for interview among those of working age, while the converse is true for those of retirement age.

While the relationship between self-reported health state prevalence and age shown in Figure 1 can be expected more or less consistently at any geographical level, it is not always observed using the APS for the smallest local areas, such as Rutland and Tower Hamlets, because of small samples leading to larger random variation (Figure 2). While the census data shows a plausible relationship with age for females in Rutland, the APS prevalence rates used in the published HLE series are irregular and display an unexpected large improvement in self-reported health among females in Rutland aged 80 to 84.

Figure 2: Annual Population Survey (APS) "Good" health rates by age for females in Rutland for the time period 2010 to 2012 and 2011 Census "Good" health rates



Source: 2011 Census; Annual Population Survey 2010 to 2012

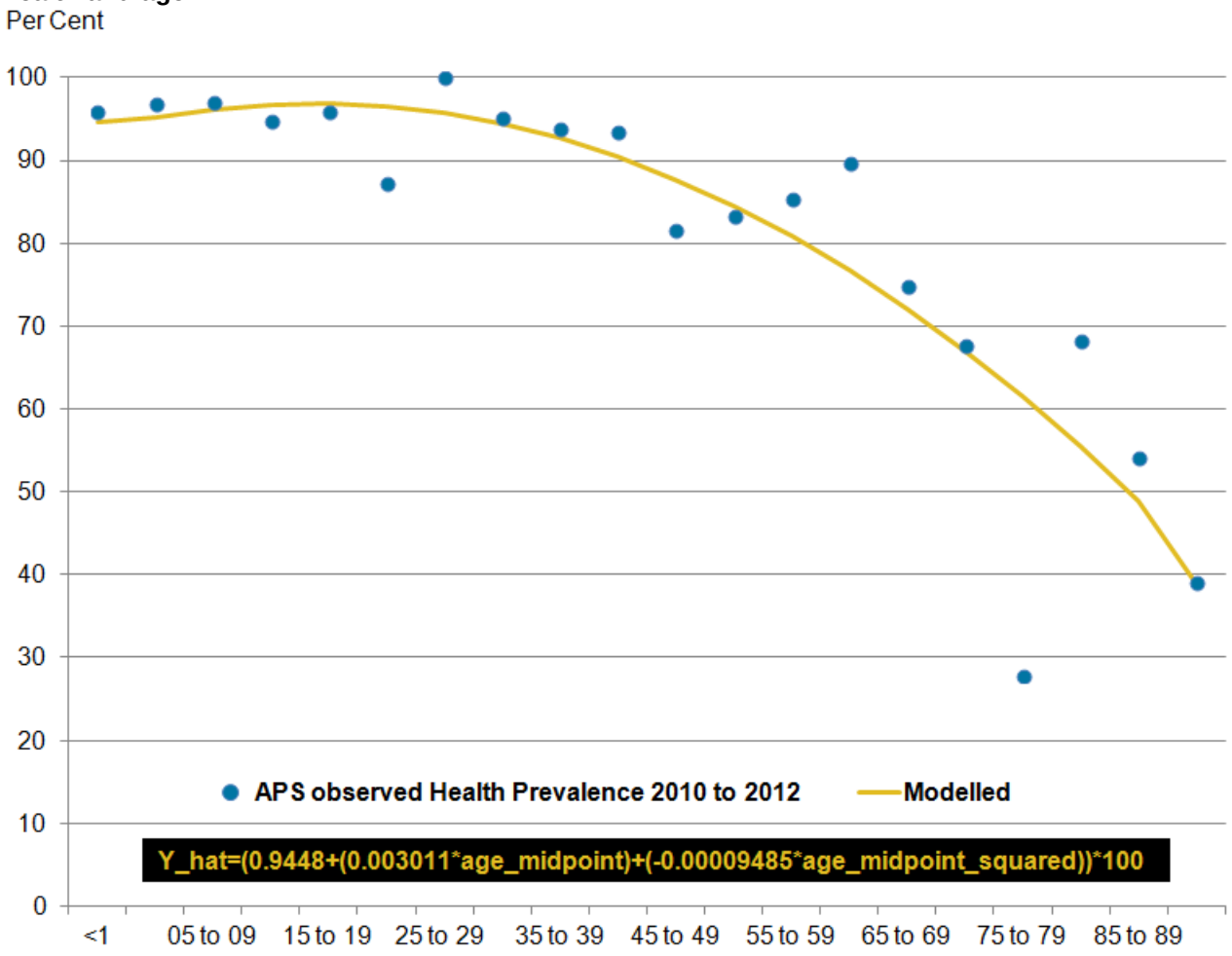
To mitigate the issue of random fluctuations producing implausibly abrupt changes in health state prevalence at a local level, this report investigates three methods, which involve estimating health (and disability prevalence) on the basis of observed data using predictive models.

5 . Modelling approach

The proposed modelling approach involves modelling self-reported health prevalence rates using a least squares regression method including a quadratic explanatory age variable. Intuitively, on a graph with age on the X axis and health state prevalence on the Y axis (Figure 3), the scattered data points would conform to a quadratic line of best fit. This has the effect of smoothing out the health prevalence distribution across age, thereby mitigating the large random fluctuations in the distributions observed in some subnational populations with smaller samples.

An individual regression line was fitted for each geographical area (local area, region, country and UK), sex and age group, since HLE and DFLE statistics are published by age, sex and geography.

Figure 3: Graph displaying a line of best fit for Rutland females in the period 2010 to 2012, computed using an ordinary least squares regression with a quadratic term, showing the relationship between health and age



A more detailed explanation of this method and the variations considered in this report (discussed in the next section) are found in the Appendix.

6 . Variations to modelling approach

We investigated three variations to the modelling approach, which each use the imputation method (see section Things you need to know about this release), where the census is used to impute health and disability-free prevalence rates for children and the two oldest age groups.

Method 1

First, the existing imputation method is applied to the raw Annual Population Survey parameter estimates to calculate ages 0 to 15 and ages 85 to 89 and 90 and over.

Second, a prevalence rate for each age group is estimated using a least squares regression taking the midpoint of the age band and its square as explanatory variables for each sex and geographical unit separately.

Method 2

First, the modelling least squares approach is applied to raw APS parameter estimates on the age groups that are available from ages 16 to 19 and 80 to 84 years.

Second, the imputation method is applied from the fitted estimates for age groups 16 to 19 and 80 to 84 to estimate prevalence rates for the remaining age groups.

Method 3

The same as Method 1, except that a census health state term is included in the least squares regression. Since healthy life expectancy (HLE) and disability-free life expectancy (DFLE) are expected to change only modestly over time, the addition of a census term in the equation has the potential to rein in exceptionally volatile data (as was observed for females in Rutland).

The geographical units investigated were the 150 upper tier local authorities in England, the 22 Welsh unitary authorities, the 32 Scottish council areas and the 11 Northern Ireland local government districts. In addition the models were also run for English regions, the constituent countries and the UK itself.

7 . Criteria to assess models

The criteria used to assess the three methods discussed in section 6 are detailed in this section.

Criterion 1

This involves comparing how closely 2010 to 2012 healthy life expectancy (HLE) estimates produced by the three methods match those based on the 2011 Census. This is measured in two ways; firstly by comparing for each method the percentage of local areas in the UK that are significantly different to the estimates based on the 2011 Census, as well as the average (absolute) deviation of estimates from the census across local areas for all age groups.

We accept the inclusion of a 2011 Census self-reported health state prevalence term in this method is likely to improve coherence of HLE estimates with regards to methods 1 and 2, alignment to estimates based on 2011 Census data remains a desirable property.

Criterion 2

This involves comparing across the three methods the average, minimum and maximum adjusted R square values, which measure the fit of each model, in each of the least squares regressions.

Criterion 3

This involves comparing across methods the plausibility of the changes in HLE over non-overlapping time periods (comparing 2010 to 2012 with 2013 to 2015 estimates). Specifically, comparing consistency in the direction of change in HLE (at the UK level and local areas) and whether the change was statistically significant compared with the published data.

It is not possible to assess Criterion 1 using disability-free life expectancy (DFLE), since disability is measured differently in the 2011 Census relative to the APS. Additionally, because of a change to the APS survey questions used to produce statistical measures of disability between 2010 to 2012 and 2013 to 2015, it is not possible to assess Criterion 3 using DFLE either. These changes to the questions are explained in the Health State Life Expectancies Quality and Methodology Information report. However, adjusted R squared statistics are available for disability-free state modelled estimates for the period 2013 to 2015 in the datasets.

The results assessing each of the methods using the three criteria are discussed in this section.

Criterion 1: Comparing HLE estimates to estimates based on 2011 Census

For the UK, (shown in Table 1) the highest percentage of areas with HLE significantly different to the census (transcribed as "PASDC" from here onwards) occurs at age 65 years across all methods, which is a likely sample selection effect. The published[1] data appear to deviate most from the census at age 65 years (36.7% of geographies) whilst Method 3 estimates fewer geographies being significantly different to the census (29.13%). The same pattern occurs at all ages, where Method 3 performs modestly better on the PASDC, but the difference across methods is minimal. At birth, Method 2 differs most from the census, but the difference between the three methods and the published data again is small.

The picture when looking at the average absolute deviation from the census is similar to the configuration of the PASDC, but more varied and therefore harder to establish a consistent pattern.

Table 1: Mean absolute difference in Healthy life expectancy (HLE) in the period 2010 to 2012 compared to the census estimates and the percentage of geographies in the UK where HLE is significantly different to the census, for each method, by age

	Method	Mean (Absolute) Difference to Census	Percentage Significantly Different to Census
Published	All Ages	0.99	21.42
	At Birth	1.27	21.10
	Age 65	1.12	36.70
Method 1	All Ages	1.01	21.20
	At Birth	1.27	21.33
	Age 65	1.09	33.49
Method 2	All Ages	0.96	20.16
	At Birth	1.32	23.85
	Age 65	1.07	33.94
Method 3	All Ages	0.98	19.78
	At Birth	1.28	21.56
	Age 65	1.03	29.13

Source: Office for National Statistics

1. Since local area estimates are unavailable for Northern Ireland for 2010 to 2012, the 11 Northern Ireland Local Government Districts are excluded. The table includes the UK, Constituent Countries, English regions and local areas in England, Wales and Scotland.

This pattern in PASDC found in local areas only across the UK is found mostly in local areas within each constituent country (shown in Table 5 in the Appendix), although for Scotland, the PASDC is higher for the at birth estimates and not at age 65, and is also generally lower using the published method followed by Method 3 in the majority of cases. However, the range of deviation across methods is minimal. Northern Ireland local areas are not included so the Northern Ireland results apply to Northern Ireland only.

Criterion 2: Comparison of adjusted R square values in modelled regressions

Table 2 displays the adjusted R squares by country within the UK by sex for the period 2013 to 2015. The data indicate that the average adjusted R squares among the local areas of each UK country is marginally higher for Method 3 (except for Northern Ireland, where Methods 1 and 3 are similar). The average adjusted R squares are highest in Wales followed by England, with an average adjusted R squared exceeding 0.80 for all methods and 0.90 for Methods 1 and 3 in these constituent countries. The average for Method 2 is lower than Methods 1 and 3 for each sex in each country.

The adjusted R squared weakens significantly for Northern Ireland for Method 2 where the average of the measure falls between 0.36 and 0.40, and is negative for males in one local area (Fermanagh and Omagh). The average for the other methods, for both sexes, just exceeds 0.60, indicating a weaker fit for Northern Ireland's local government districts. This may indicate that for some areas in Northern Ireland, the APS data are particularly volatile, such that the usual relationship between health and age is not found and cannot be easily corrected through modelling.

Table 2: Comparing the average, minimum and maximum adjusted R squares for the three modelling methods across all local areas in each of the countries in the UK, by sex 2013 to 2015

		Method 1			Method 2			Method 3		
Country	**Sex**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**
England	Males	0.92	0.54	0.98	0.84	0.45	0.96	0.92	0.52	0.99
	Females	0.92	0.03	0.99	0.84	0.23	0.98	0.93	0.30	0.99
Wales	Males	0.93	0.83	0.97	0.84	0.56	0.94	0.93	0.84	0.97
	Females	0.93	0.77	0.98	0.83	0.43	0.97	0.93	0.75	0.98
Scotland	Males	0.86	0.10	0.97	0.78	0.11	0.95	0.87	0.11	0.97
	Females	0.88	0.20	0.97	0.76	0.03	0.94	0.89	0.23	0.97
Northern Ireland	Males	0.60	0.27	0.86	0.36	-0.06	0.77	0.60	0.24	0.86
	Females	0.61	0.07	0.91	0.40	0.03	0.81	0.61	0.02	0.92

Source: Office for National Statistics

There is no clear pattern between sexes; generally the average adjusted R squared is very similar for each sex.

The datasets for DFLE contain the adjusted R squared values for each area by sex.

Criterion 3: Comparison of change in HLE between 2010 to 2012 and 2013 to 2015 by method and including published data

It is important to look at how estimates of HLE change over a non-overlapping time period (in this case, between 2010 to 2012 and 2013 to 2015) to judge how the methods compare with estimates using the existing published method. Table 3 shows the direction of change in HLE observed for the UK using each method and the published data.

The published data found a statistically significant improvement in HLE for both males and females at age 65 and non-significant gains at birth for each sex. Methods 1 and 3 only found a significant improvement for males at age 65 years and non-significant gains at birth and for women aged 65 years. Method 2 had no statistically significant changes, but contrary to the published and other methods, found a fall in female HLE at birth.

Table 3: Comparing the direction of change and significance of HLE between 2010 to 2012 and 2013 to 2015 in the UK for the 3 modelling methods and published method, and the number of local areas that experienced a positive change in HLE between those time periods, by sex and age

Method	Sex and Age	Direction of change	Is it statistically signifiant?	Number of local areas that positively changed over time
Published Method	Males at Birth	+	Not Significant	117
	Males at age 65	+	Significant	136
	Females at Birth	+	Not Significant	108
	Females at age 65	+	Significant	117
Method 1	Males at Birth	+	Not Significant	116
	Males at age 65	+	Significant	132
	Females at Birth	+	Not Significant	108
	Females at age 65	+	Not Significant	115
Method 2	Males at Birth	+	Not Significant	122
	Males at age 65	+	Significant	129
	Females at Birth	-	Not Significant	107
	Females at age 65	+	Significant	119
Method 3	Males at Birth	+	Not Significant	116
	Males at age 65	+	Significant	134
	Females at Birth	+	Not Significant	108
	Females at age 65	+	Not Significant	112

Source: Office for National Statistics

1. The local areas analysed in this table include those in England, Wales and Scotland. 2010 to 2012 local data for Northern Ireland is not included, since local area data for this time period was unavailable.

Across all methods, the number of local areas where HLE estimates increased over time was broadly similar, but there were more instances of gains at age 65 compared with at birth consistently across all methods.

For males at birth, both Methods 1 and 3 found four local areas to have experienced a statistically significant improvement in HLE and no statistically significant falls in line with published data. Method 2 found seven instances where HLE increased significantly. For males at age 65 years there was one instance (Westminster) of a statistically significant fall in HLE using Methods 1 and 3, and six instances of statistically significant increases. In published data there were also six local areas that had a statistically significant increase but no significant falls. Method 2 observed four local areas with statistically significant increases and no significant falls.

For females at birth, published data and Methods 1 and 3 had three instances of local areas significantly improving their HLE and three witnessing significant falls. For Method 2 there were four significant falls and two significant increases. At age 65 years, significant gains in HLE numbered five for Methods 2, 3 and published with one significant fall. Method 1 observed six significant increases and one significant fall.

Statistically significant changes at local area level between adjacent non-overlapping time periods are small in number and expected to be so, partly because of the width of the confidence intervals and partly because meaningful change in HLE is not expected over short time horizons. The coherence between the published and each method tested in the scale of statistically significant changes is reassuring.

Based on the three criteria discussed previously, we propose to use Method 3 since it has the strongest model fit for self-reported health state prevalence, as determined by the R square statistic and the smallest proportion of age group specific HLE significantly different to those based on 2011 Census prevalence data. It also has the smallest mean absolute deviation in HLE from the 2011 Census-based estimates across all ages, at birth and at age 65 years. However, while Method 3 will be discussed in detail shortly, the same measures reported for it are available for the other methods tested in the datasets.

Notes for: Criteria to assess models

1. For Wales and Scotland, the published method has been used, but these statistics have not been published previously. Northern Ireland local areas are excluded, but Northern Ireland itself is included.

8 . Results using the proposed method

This section explores the effect of the proposed method on the health prevalence rates and HLE relative to the 2010 to 2012 published data and estimates based on 2011 Census data, as well as the change over time between 2010 to 2012 and 2013 to 2015. These comparisons are made focusing on the effects at the UK level and on the smallest local areas, where data is particularly sparse, namely Tower Hamlets, Rutland and the Orkney Islands. This enables a comparison of the impact of this method at the highest geographical level and the smallest areas where sample sizes are weakest. An interactive graph is also available, where it is possible to pick any area within the UK (where the data are available) and filter by sex and age group (at birth and at age 65) to look at the impact of adopting the proposed method.

Comparing the health prevalence rate

When all males in the UK are selected in Figure 4 (or females in Figure 5), it is clear that the proposed method and the published prevalence rates follow each other closely and show the expected relationship between health and age. After age group 65 to 69, the census data are slightly lower for the remaining age groups. Yet this difference is quite minimal. Similar results, where the census diverges at older ages, are found for most of the larger geographies, such as countries, English regions and most English counties for each sex. The published data differs slightly more from the 2011 Census at the UK level than the modelled, but does have a smooth prevalence curve with regard to age.

Figure 4: A comparison of the census, published and the proposed method for estimating health state prevalence rates for males by age for national, regional and local areas in the UK 2010 to 2012

Notes:

1. Excludes Northern Ireland's Local Government Districts as data were not available for these geographies.

Focusing on the prevalence rates of the selected lower geographies, the published data are irregular and particularly for older ages,[1] while the proposed method reduces irregularity, but remains somewhat distant from the census.

If males in Rutland are selected in Figure 4, up to age 60 to 64 years, general health prevalence using the proposed method, although slightly erratic, follows the census data quite well, while the published data fluctuate more. After this age group, the prevalence rates calculated by the proposed method fall notably and much more so than the census, while the published data deviate erratically around the modelled prevalence. For age group 90 and over, the census prevalence rates are much higher relative to the proposed method and the published data, explaining the large contrast in published and modelled HLE in 2010 to 2012 compared with 2011 Census-based estimates in Rutland.

If females in Rutland are selected in Figure 5, the proposed method produced self-reported health prevalence rates which were also much smoother and not unexpectedly increasing and decreasing notably between adjacent age groups like the observed published data. However, the proposed method’s estimates are higher than the census, for the age groups above 70 to 74, while the published data fluctuate above and below the census for these age groups.

Figure 5: A comparison of the census, published and the proposed method for estimating health state prevalence rates for females by age for national, regional and local areas in the UK 2010 to 2012

Notes:

1. Excludes Northern Ireland's Local Government Districts as data was not available for these geographies.

Generally, for Tower Hamlets and the Orkney Islands for both sexes, the proposed method health prevalence rates are much closer to the census while the published data erratically weaves around the modelled rates. However, for some age groups, the proposed method diverges more from the census than the published data.

Although the modelled prevalence rates are somewhat distant from the census for some areas and some age groups, the pattern is much more plausible with regard to the expected relationship between self-reported health and age, with good general health status declining with age in a conventional way. The effect on HLE is discussed in the next section.

Comparing HLE based on the 2011 Census, published and proposed method

Looking now at healthy life expectancy (HLE) (Figure 6), it appears that although the proposed method has quite a large effect on the pattern and size of prevalence rates for the smaller geographies, the effect on HLE is less acute. A reason for this may be that HLE by age group is calculated using prevalence rates for future age groups and therefore this may smooth out the effect of random fluctuations. The modelled estimates at birth align modestly better than the published data to the estimates based on 2011 Census health prevalence data for males and modestly worse for females. However, when taking account of all ages and especially older ages, the modelled estimates calculated using the proposed method align much closer to the 2011 Census estimates than the published data do for both sexes.

Figure 6: A comparison of the census, published and the proposed method HLE estimates in years, for males and females at birth and age 65 in selected areas (UK shown), 2010 to 2012

Notes:

1. Excludes Northern Ireland's Local Government Districts as data were not available for these geographies.

For males and females at the UK level in 2010 to 2012, HLE at birth shows very little difference between the published and modelled estimates, which are both slightly lower than the census at birth (less than a year) and higher at age 65 years. At age 65 years, this gap widens to over one year for females, though the modelled estimates are on average 0.2 years closer to the census-based estimates than the published data.

At lower geographies the HLE estimates are more volatile. For example, in Rutland, HLE at birth for the period 2010 to 2012 calculated using the census health state prevalence data is 3.6 years higher for males than published and modelled estimates; however, for females HLE at birth is much closer to the census, with the published data 0.4 years higher and the modelled estimates 0.6 years higher.

The sizeable difference for males in Rutland demonstrates the limitations of small samples to reliably estimate self-reported health and as a consequence, HLE. Interestingly, despite the volatility of the published prevalence rates for males and females from age 65 years in Rutland, the published HLE estimates are in fact slightly closer to the census-based estimates but still markedly distinct.

For Tower Hamlets, there is a similarly large difference for males at birth, where HLE produced using the census is around four years higher than the proposed method and the published data. However, for most other areas, the differences are much smaller. The proposed method had a mean deviation from the census of 1.22 years, as 50% of local areas had deviations less than a year and 75% had deviations within 1.75 years for males. For females, the mean deviation was larger at 1.41 years, with 50% of areas within 1.06 years and 75% within 1.93 years.

Male HLE at age 65 years calculated using the proposed method had a mean deviation from the census-based estimates of 0.99 years, with 50% of local areas within 0.87 years and 75% of local areas within 1.46 years. For females, the mean deviation at age 65 years was larger at 1.10 years, as 50% of local areas were within 0.98 years and 75% were within 1.52 years.

The interactive chart in Figure 6 allows users to select their own area and produce HLE comparison charts similar to that for the UK.

Comparing the change in HLE between 2010 to 2012 and 2013 to 2015

Finally, when looking at HLE changes over time, Figure 7 shows that male HLE at birth for both the published and the proposed method-based estimates increased between 2010 to 2012 and 2013 to 2015 by 0.24 and 0.23 years respectively. HLE also increased in England by 0.22 years both in published and proposed method estimation. Larger gains were observed in Scotland and Northern Ireland, but in Wales the published and proposed method estimated a small fall of 0.03 and 0.05 years respectively. At age 65, there were larger increases in HLE than at birth. The proposed method produced slightly smaller increases than the published data, except in Northern Ireland where it was larger.

For females at birth, there was a small increase in the UK in both the proposed and published estimates of a similar magnitude. In Scotland, small falls were observed but the fall was less under the proposed method of 0.08 years. In Northern Ireland, larger falls of 0.40 and 0.35 years were observed by method respectively. In Wales, gains were observed of 0.40 and 0.42 years respectively, while in England small gains were observed.

When considering the smallest areas, however, it is clear that the direction of change is not always consistent. For males at birth, there was one instance (Medway) where the published estimates showed a small increase in HLE of 0.03 years, while the proposed method estimates a small fall of 0.05 years. All other local areas moved in the same direction over time. At age 65 years, there were 22 areas travelling in different directions, among which were Gwynedd, Tower Hamlets, Scottish Borders and Hounslow, but these were not significant.

For females at birth, all local areas travelled in the same direction in published and modelled estimates; however, at age 65 years there were 21 local areas travelling in a different direction including Newport, East Dunbartonshire, Islington and South Tyneside. However, these changes in HLE were not statistically significant.

Figure 7: The change in HLE between 2010 to 2012 and 2013 to 2015 for the published and the proposed method, for males and females at birth and age 65

Notes:

1. Excludes Northern Ireland's Local Government Districts as data were not available for these geographies.

Table 4 shows a comparison of the change in HLE at all ages between 2010 to 2012 and 2013 to 2015 for the proposed method and the published estimates across local areas in each of the UK countries. Although the proposed method and published estimates reveal quite similar results, the average, minimum, maximum and percentage of local areas that significantly changed between 2010 to 2012 and 2013 to 2015 were typically higher using the published method relative to the proposed method, suggesting the published estimates have less stability overtime.

When comparing across countries, the average change over time for all age groups in local areas in England for males was 0.29 years in a positive overall direction, with 59.0% of age groups increasing their HLE, 1.83% experiencing a statistically significant increase and 1.97% significant changes in total. The published estimates had an average change over time of 0.31 years in a positive overall direction, with 58.4% of age groups increasing their HLE; 1.97% had a statistically significant increase and 2.40% significant changes in total.

For females in England, the average change using the proposed method was smaller in a positive direction at 0.12 years, with 51.9% of age groups increasing their HLE and 0.77% increasing significantly, while there were 1.50% of age groups having a statistically significant change in total. The published estimates had an average change over time of 0.14 years in a positive overall direction, with 52.4% of age groups increasing their HLE, 0.93% increasing significantly and 0.77% decreasing significantly.

Table 4: Comparing change in HLE estimates between 2010 to 2012 and 2013 to 2015: the proposed method and published method estimates for local areas in each UK country [2]

			Change in Healthy Life Expectancy between 2010 to 2012 and 2013 to 2015			
Sex	**Method**	**Country**	**Average**	**Range**		**Percentage Significantly Different**
Males	Proposed Method	England	0.29	-4.37	6.85	1.97
		Scotland	0.56	-3.48	4.23	0.94
		Wales	0.39	-2.09	3.56	2.27
		Northern Ireland	0.50	0.21	0.88	0.00
	Published Method	England	0.31	-5.54	6.89	2.40
		Scotland	0.57	-3.44	4.34	0.31
		Wales	0.43	-2.37	3.72	2.27
		Northern Ireland	0.48	0.12	0.90	0.00
Females	Proposed Method	England	0.12	-5.04	6.78	1.50
		Scotland	0.14	-4.47	5.05	6.41
		Wales	0.51	-1.93	4.46	2.95
		Northern Ireland	-0.18	-0.41	0.00	0.00
	Published Method	England	0.14	-5.27	8.46	1.70
		Scotland	0.19	-4.59	5.22	7.03
		Wales	0.54	-2.18	4.06	3.18
		Northern Ireland	-0.11	-0.45	0.30	0.00

Source: Office for National Statistics

1. Data for Northern Ireland is not comparable as the data for local areas is not available for 2010 to 2012. Therefore country level estimates have been used instead.

The average change under the proposed method for males across all age groups and local areas in Scotland was an increase of 0.56 years, with 68.8% of age-groups increasing its HLE, although only 0.94% showed a statistically significant increase and no significant decreases. The published method's equivalent figures were 0.57 years, 67.2% increasing and 0.31% increasing significantly.

For females in Scotland across all age groups and local areas, the proposed method showed HLE increasing on average by 0.14 years. Of all age groups, 48.30% increased their HLE, although significant increases were observed in only 5.31% of age groups and there were significant decreases in 1.10% of age groups. Significant increases were therefore more numerous for females in Scotland than in England and males in Scotland. In published estimates the equivalent figures were moderately higher; 0.19 years average increase in HLE, 50.50% of age groups increasing, with 5.31% increasing significantly and 1.72% decreasing significantly.

The average change in HLE at birth under the proposed method for males across all age groups and local areas in Wales was an increase of 0.39 years, with 62.30% of age groups increasing their HLE, although only 2.27% showed a statistically significant increase. In published data, the equivalent figures were 0.43 years, 63.20% increasing and 2.05% increasing significantly.

For females in Wales across all age groups and local areas, the proposed method showed HLE increasing on average by 0.51 years. Of all age groups, 62.3% increased their HLE, although significant increases were observed in only 2.95% of age groups. In published estimates, the equivalent figures were 0.54 years average increase in HLE, 50.5% of age groups increasing, with 5.31% increasing significantly and 1.72% decreasing significantly.

Change overtime is characteristically higher for Scotland and Wales, while the minimum and maximum changes are generally highest for England. The percentage of areas statistically significantly different between 2010 to 2012 and 2013 to 2015 are highest in England and Wales for males and in Wales and Scotland for females. However, statistically significant changes are small in number and would be expected to be so generally over a short time horizon. In terms of statistically significant changes across local areas, the proposed method mostly produces a lower number of significant differences than the published estimates.

Given that Northern Ireland estimates are created using country rather than local level data, these data should not be compared with the other countries, but the change in Northern Ireland as a whole is shown.

Notes for: Results using the proposed method

1. This corresponds with the results from Table 3, where the published, and to a lesser extent the proposed method HLE estimates for local areas differed most from the census at age 65 years.

2. Data for Northern Ireland are not comparable, as the data for local areas are not available for 2010 to 2012. Therefore, country level estimates have been used instead.

9 . Conclusion

This report has presented analyses undertaken by Office for National Statistics (ONS) to investigate possible alternative ways of estimating age- and sex-specific health state prevalence for use in estimating health state life expectancies in the future. We have stated a preference for using Method 3 for future reporting of these summary measures of population health across geographical areas and by measures of deprivation, as this method performed better than the others and the published method using the criteria described previously. However, it is important to get feedback from users on the merits of this method. In particular, views are invited on the balance between complexity and ease of understanding of what has been done in producing these estimates for the general reader.

The implementation of Method 3 would not cause a major discontinuity in these statistics and has the added benefit of reducing the sizeable trajectories over time in healthy life expectancy (HLE) observed in some local areas under the existing published method. It also produced more plausible health state prevalence rates and had greater conformity to the patterns observed in 2011 Census data.

The adjusted R squares for Method 3 were the strongest overall and the average model fit suggested age and its square together with the prevalence found at census were good predictors.

We are running a consultation on the proposed method described in this report to gain feedback from users on the proposed change before it is implemented. We have presented the analysis and chosen a preferred method but would not want to lead users until they have had time to consider the report and accompanying statistics. Therefore, we welcome responses to the consultation within the next eight weeks.

10 . Appendix: Healthy life expectancy methods and variants

Table 5: Mean absolute difference in healthy life expectancy (HLE) compared with the census estimates by method and the percentage of local areas where HLE is significantly different to the census by age and UK countries, 2010 to 2012

Country	Method	Age Group	Mean (Absolute) Difference to Census	Percentage Significantly Different to Census
England	Published	At Birth	1.18	14.67
		At Age 65	1.16	35.00
		All Ages	0.98	17.12
	Method 1	At Birth	1.18	14.67
		At Age 65	1.11	29.67
		All Ages	0.99	16.95
	Method 2	At Birth	1.24	18.33
		At Age 65	1.10	32.33
		All Ages	0.95	16.32
	Method 3	At Birth	1.19	15.00
		At Age 65	1.06	26.00
		All Ages	0.96	15.25
Northern Ireland	Published	At Birth	0.64	0.00
		At Age 65	0.80	100.00
		All Ages	0.78	57.50
	Method 1	At Birth	0.65	0.00
		At Age 65	0.84	100.00
		All Ages	0.84	52.50
	Method 2	At Birth	0.90	0.00
		At Age 65	0.73	50.00
		All Ages	0.84	52.50
	Method 3	At Birth	0.65	0.00
		At Age 65	0.69	50.00
		All Ages	0.77	52.50
Scotland	Published method	At Birth	2.28	46.88
		Age 65	0.70	6.25
		All Ages	1.20	21.86
	Method 1	At Birth	2.31	48.44
		At Age 65	0.83	15.63
		All Ages	1.24	22.64

	Method 2	At Birth	2.25	48.44
		At Age 65	0.73	6.25
		All Ages	1.16	18.35
	Method 3	At Birth	2.29	48.44
		At Age 65	0.78	10.94
		All Ages	1.21	20.53
Wales	Published method	At Birth	0.84	4.55
		Age 65	1.49	54.55
		All Ages	0.98	19.55
	Method 1	At Birth	0.80	4.55
		Age 65	1.40	47.73
		All Ages	0.99	19.32
	Method 2	At Birth	0.87	4.55
		Age 65	1.41	47.73
		All Ages	0.98	18.75
	Method 3	At Birth	0.81	4.55
		Age 65	1.29	38.64
		All Ages	0.95	18.07

Source: Office for National Statistics

Notes:

1. The published method has been used for Scotland and Wales as these estimates have not been published previously.

2. Data for Northern Ireland is not comparable as the data for local areas is not available for 2010 to 2012. Therefore country level estimates have been used instead.

General method

The proposed modelling approach involves modelling the health prevalence rates using the least squares method with a quadratic term, as follows:

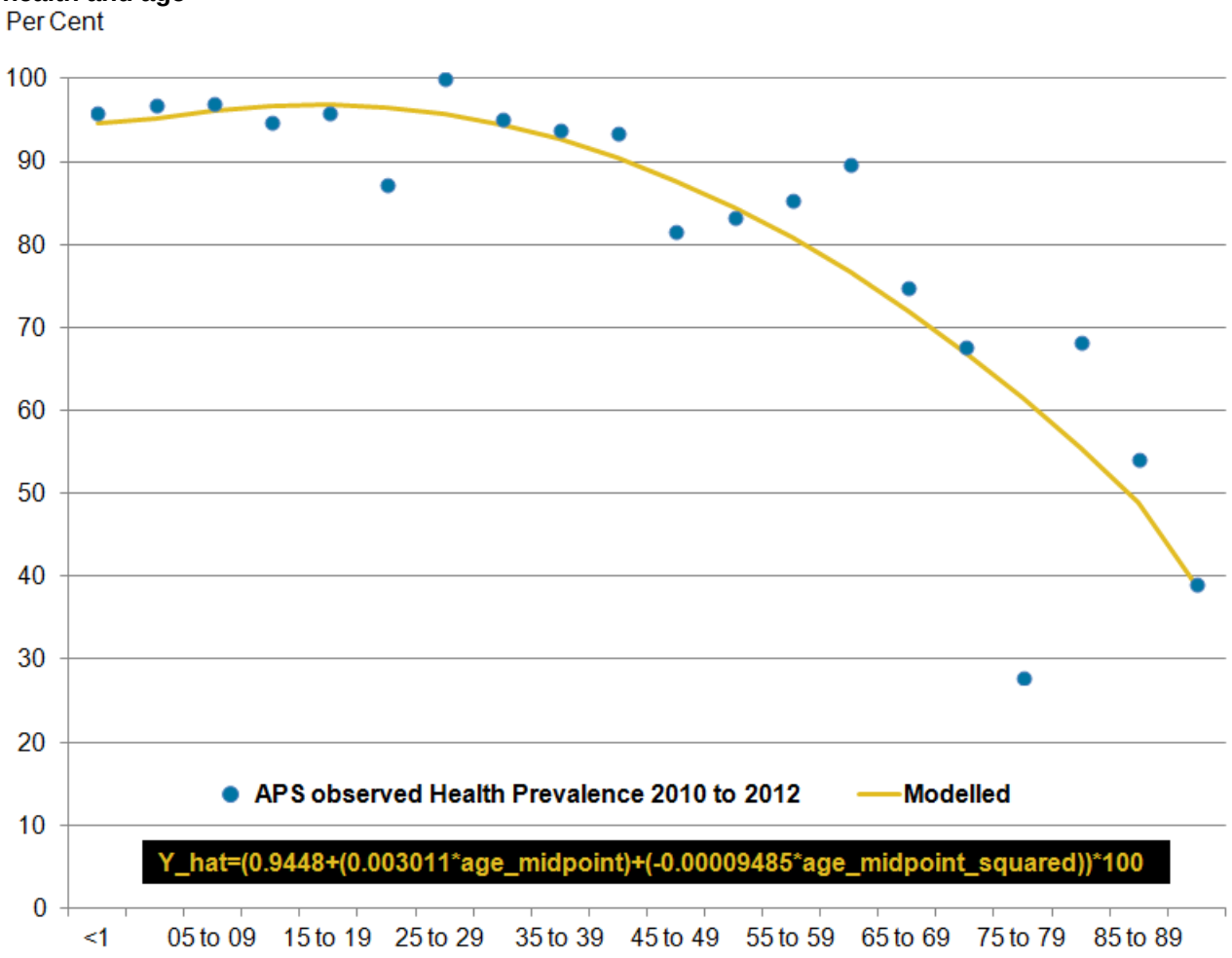
$$Y = a + b_1 x_1 + b_2 x_2^2 + b_i x_i \ldots\ldots + e$$

The mid-point of each age group is substituted as the value in this equation and the health parameter estimate as the value, as is depicted in the following equation:

Predicted Good Health prevalence = constant + b_1*age midpoint + b_2*age midpoint^2

From this equation, it is possible to obtain the coefficients for the constant (a) and the coefficients (b_i). By deriving the mid-point of each age group and plugging in the coefficient values into this equation, yields estimated values, which form a quadratic line of best fit. This line of best fit, using the least squares method, is formed such that it minimises the total sum of squares of the differences between the observed values from the expected values (on the line of best fit) as demonstrated in Figure 8 (this was reported as Figure 3 in the main report).

Figure 8: Graph displaying a line of best fit for Rutland females in the period 2010 to 2012, computed using an ordinary least squares regression with a quadratic term, showing the relationship between health and age



In practice, the line of best fit is found through regression of the mid-point of the age-group and the mid-point of the age-group squared on the health prevalence rate. The mid-point of each age-group is chosen, because this enables the distance between age groups to be taken into account in the regression. An individual regression is done for each geographical code (local area, region, country and UK) and sex, since HLE and disability-free life expectancy (DFLE) statistics are published by sex and geography.

Table 6 provides an example of how the modelled values are calculated. Using the data in the table and regressing the mid-point of each age group and the mid-point of each age group squared on the good health rate, yields the beta and constant coefficients for all age groups for females in Rutland. The coefficient values and the age-group midpoint and age-group midpoint squared values can then be subbed back into the regression equation to find the modelled prevalence estimates or fitted values for each age group. These modelled health prevalence estimates can then be used to calculate HLE.

Table 6: Regression Table from Modelling[1] Health Prevalence Rates for females in Rutland

Age Group	Good Health Rate	Mid point Age Group	Mid Point Age Group Squared	Fitted	Beta_ midpoint	Beta_midpoint _squared	Constant
Less than 1	0.9591	0.5	0.25	0.94630	0.00301	-0.00009	0.94482
01 to 04	0.9688	2.5	6.25	0.95176	0.00301	-0.00009	0.94482
05 to 09	0.9704	7	49	0.96125	0.00301	-0.00009	0.94482
10 to 14	0.9487	12	144	0.96729	0.00301	-0.00009	0.94482
15 to 19	0.9587	17	289	0.96859	0.00301	-0.00009	0.94482
20 to 24	0.8725	22	484	0.96515	0.00301	-0.00009	0.94482
25 to 29	0.9999	27	729	0.95697	0.00301	-0.00009	0.94482
30 to 34	0.9528	32	1024	0.94404	0.00301	-0.00009	0.94482
35 to 39	0.9378	37	1369	0.92637	0.00301	-0.00009	0.94482
40 to 44	0.9349	42	1764	0.90396	0.00301	-0.00009	0.94482
45 to 49	0.8170	47	2209	0.87680	0.00301	-0.00009	0.94482
50 to 54	0.8340	52	2704	0.84491	0.00301	-0.00009	0.94482
55 to 59	0.8541	57	3249	0.80827	0.00301	-0.00009	0.94482
60 to 64	0.8968	62	3844	0.76689	0.00301	-0.00009	0.94482
65 to 69	0.7494	67	4489	0.72076	0.00301	-0.00009	0.94482
70 to 74	0.6771	72	5184	0.66990	0.00301	-0.00009	0.94482
75 to 79	0.2786	77	5929	0.61429	0.00301	-0.00009	0.94482
80 to 84	0.6829	82	6724	0.55393	0.00301	-0.00009	0.94482
85 to 89	0.5414	87	7569	0.48884	0.00301	-0.00009	0.94482
90 and over	0.3911	94	8836	0.38974	0.00301	-0.00009	0.94482

Source: Office for National Statistics

Notes:

1. This table uses model 1 estimates (discussed on page 10). The proposed method would have an additional census prevalence coefficient.

In some cases, particularly for the lowest and highest age groups, the fitted values can exceed the parameter estimate boundaries of zero and one. When this has happened, the fitted values have been capped at zero and one before estimating HLE and DFLE.

Variations to method

As discussed in this report, we investigated three variations to the modelling approach, which each use the imputation method (see section Things you need to know about this release), where the census is used to inform health prevalence rates at ages where data are missing or sparse.

For Method 1, the imputation method to calculate data for age groups not collected or where data are sparse was applied before the least squares regression to generate fitted values. For Method 2, on the other hand, the regression is applied first and then the imputation method is applied after the event. For both these methods, the same variables are included to the previous equations.

The regression equation for Methods 1 and 2 is as follows:

$$Health\ Paramater\ Estimate = a + b_1 * agemidpoint + b_2 * agemidpoint^2$$

For Method 3, a census prevalence term is also added to the equation and the modelling of the health prevalence rates occurs on both observed and imputed values in the same way as Method 1. Since HLE is expected to change slowly over time, the addition of a census term in the equation has the effect of adding stability to local areas with particularly volatile data (as was observed for females in Rutland).

The regression equation for Method 3 is as follows:

$$Health\ Paramater\ Estimate = a + b_1 * agemidpoint^2 + b_2 * agemidpoint + b_3 * censusprevalence$$

11 . References

Miles J (2014), R Squared, Adjusted R Squared, Wiley StatsRef: Statistics Reference Online

Office for National Statistics (2016), Method changes to health state life expectancies

Office for National Statistics (2016), Health state life expectancies Quality and Methodology Information report