HEALTHY LIFE EXPECTANCY MEASUREMENT IN SCOTLAND

By Angus Macdonald, Jennifer Straughn and Matt Sutton

ABSTRACT

Health expectancy (HE) was only recently estimated for the Scottish population (Clark *et al.*, 2004). The estimates were based on Sullivan's method, applying the morbidity prevalence in each age group to the expected number of years lived, to obtain the expected number of years lived in good health. First, we compare these estimates with a wide range of estimates in respect of the rest of the United Kingdom and the (pre-accession) countries of the European Union. We find that Scotland's HE is relatively low, especially for men. Second, we examine data comprising the responses to the 1998 Scottish Health Survey, linked to the hospital records of the respondents from 1981–2004, and death records from 1998–2004, with HE measurement in mind. Although time spent in hospital does not give a satisfactory measure of HE, the linkage presents a rare opportunity for statistical analysis of survey respondents' mortality and morbidity. We show the results of survival analyses, quantifying the effectiveness of various definitions of 'unhealthy' as predictors of future mortality and morbidity. The results suggest that enumerating recent serious hospital episodes might help to predict future patterns of demand for acute services.

KEYWORDS

Health Expectancy; Hospital Episodes; Life Expectancy; Scottish Health Survey

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1. Introduction

1.1 *Background*

The Faculty of Actuaries in Scotland celebrates its 150th anniversary in 2006. As part of the program of events to mark the occasion, Faculty Council decided to sponsor a research project that should focus on the mutual interests of the profession and policy-making bodies in Scotland. At about the same time, the Information Services Division (ISD) of the Scottish Executive was completing the first report on Health Expectancy (HE) in Scotland (Clark *et al.*, 2004) and this work identified several key questions whose answers would help to interpret the results. Moreover, instruments very like those used to construct the HE estimates had also recently been the basis for linking the hospital records of individual people into a longitudinal data set spanning more than 20 years. Researchers have long recognized that better estimates of HE depend on collecting longitudinal data, but very little suitable data exists. The fact that such data have been developed in Scotland is a result of the relative stability of health service provision over several decades,

and far-sighted decisions made over 20 years ago that led to the systematic collection of health statistics, and the establishment of what evolved into ISD.

This combination of topicality and longitudinal data led to the choice of HE as the subject of the Faculty's research project, which was commissioned in the form of a collaboration between the Department of Actuarial Mathematics and Statistics at Heriot-Watt University, the Health Economics Research Centre at the University of Aberdeen, and with the active involvement of ISD.

Putting Scottish HE into its proper context raises several questions, identified as research priorities by ISD following the publication of Clark *et al.* (2004). First there is the apparently simple question of where Scotland, or different parts of Scotland, place in the international league table of HE. But, in explaining any differences that may be revealed, methodological questions arise. Most HE estimates to date have relied on a very simple approach called Sullivan's method, whose chief virtue is that it can be compiled quickly and simply using existing life tables and population surveys. Its drawbacks have long been recognised but better methods rely on the collection of longitudinal data, a laborious task that is only now beginning to bear fruit.

The project, and this paper, has two parts. First, we present an international comparison of HE in Scotland and in other European countries, including other parts of the United Kingdom. Second, we carry out a preliminary investigation of HE based on a unique data set compiled by ISD, namely the near-complete linkage of the responses made by the individuals included in the 1998 Scottish Health Survey (SHeS), with their hospital records since 1981. It is clear that the hospital records add a longitudinal component to the survey data that would be used in conventional HE estimates, and the question is whether, or not, this will help to form a more objective definition of HE.

1.2 *What is Health Expectancy?*

Life expectancy (LE) has been estimated in many countries for many years, being easily computed using normal census and/or death registration data. It has increased significantly in the 20th century (at least in the developed world), leading to the question of what quality of life may be experienced in the extra years lived. Health expectancy (HE) is a measure of this quality of life: if LE is simply the number of years a person may be expected to spend alive, HE is the number of years they are expected to spend in a state of good health. Naturally, this leads to the question of what determines whether one is 'healthy' or 'unhealthy'. Some authors have defined good health as freedom from long term disability both mental and physical, while others have confined it to mean the ability to undertake activities of daily living. As we will see later, HE is accepted as a generic term covering the full range of definitions for LE adjusted for health status. The relationship between HE and LE is disputed, and is not yet at all clear.

(a) Gruenberg (1977) and Kramer (1980) contended that increased LE was merely a result of a prolonged period living with disability and disease. This concept was formalised by Olshansky *et al.* (1991) as the 'expansion of morbidity' hypothesis, characterised by a decline in the ratio of HE to LE.

(b) Fries (1980, 1989) suggested that the prolonging of life would result in a compression of morbidity since, assuming that the timing of morbidity events could be postponed, the onset of diseases would be confined to the final years of life.

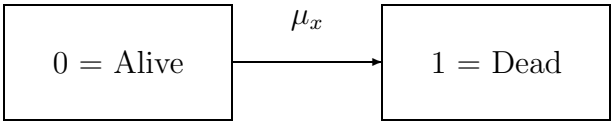

Figure 1: A two state model of the mortality of an individual, with force of mortality μ_t.

(c) Manton (1982) suggested that a slowing-down in the progression of disease would lead to a dynamic equilibrium, a simultaneous increase in LE as well as unhealthy years. Thus, an inverse relationship between mortality and morbidity might develop, but at the same time the disabilities experienced would be less severe.

Policymakers were very attuned to the debate and subsequently shifted their focus to using HE rather than LE as primary indicators of health. Researchers have responded to this demand for HE estimates, not only at the national level, but also sub-nationally and by socioeconomic groups. Robine & Ritchie (1993) reported that HE estimates had been made for some 49 countries, the earliest in Europe being in France (Robine *et al.*, 1986), followed by England and Wales (Bebbington, 1988) and the Netherlands (van Ginneken & Bonte, 1989; van Ginneken *et al.*, 1991). Robine & Romieu (1998) later reported that 13 of the 15 countries in the European Union had calculated HE estimates and that chronological series existed for Denmark, Finland, France, Germany, the Netherlands, Spain, Sweden and the UK. Within the UK, however, HE estimates were available only for England and Wales until Clark *et al.* (2004) published estimates for Scotland.

An international comparison of Scottish population health was previously undertaken by Leon *et al.* (2003), but using LE estimates together with causes of death and ill-health as health indicators. They found that among European women, Scottish women had the worst health, and among European men, Scottish men had the second worst. It is against this background that we hope that the present study can shed more light on the health of the Scottish population and in so doing be more informative to its health-care policy-makers. The study is presented as follows. Section 2 examines the different methods used to estimate HE. Section 3 reviews what is known about HE in Scotland, which is mostly due to Clark *et al.* (2004), then Sections 4 to 7 attempt to relate these to other national and sub-national studies; in particular we compare Scottish HE with most highly-standardised available European figures in Section 5. In Sections 8 and 9 we describe the SHeS and its linkage to hospital records, and in Sections 10 to 11.4 we explore aspects of these data as they may relate to HE estimation. Our conclusions are in Section 12.

2. Definition and Estimation of Health Expectancy

2.1 *Basic Idea of Health Expectancy*

The familiar expectation of life at age x may be written as:

$$e_x = \int_0^\infty {}_tp_x \, dt. \tag{1}$$

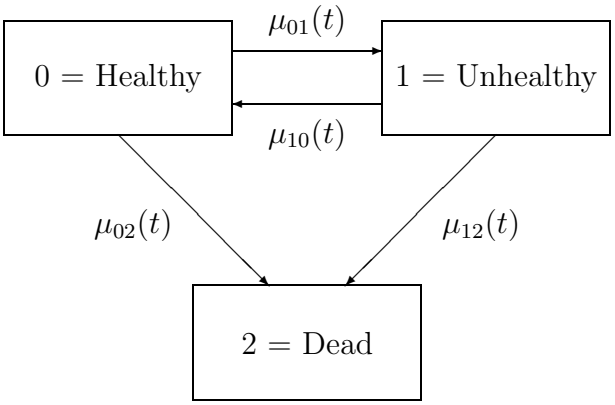

Figure 2: A three-state model of states of health.

To justify the name 'expectation' we of course ought to specify the model in which this is indeed the expected value of a suitable quantity. The simplest way that points us in the right direction is to adopt the 'alive–dead' model illustrated in Figure 1. Suppose a person is in state j at age x; then for each state k in the model define the indicator $I_{x,t}^{jk}$ to have value 1 if the person is in state k at age $x+t$, and have value 0 otherwise. This family of stochastic processes defines the individual's life history (actually with some redundancy here because of the simplicity of the model).

Define $p_{x,t}^{jk}$ to be the probability that a person in state j at age x is in state k at age $x+t$. That is, $p_{x,t}^{jk} = \mathrm{P}[I_{x,t}^{jk} = 1] = \mathrm{E}[I_{x,t}^{jk}]$. The time spent in state k is:

$$\int_0^\infty I_{x,t}^{jk}\, dt \tag{2}$$

whose expected value is:

$$\mathrm{E}\left[\int_0^\infty I_{x,t}^{jk}\, dt\right] = \int_0^\infty \mathrm{E}[I_{x,t}^{jk}]\, dt = \int_0^\infty p_{x,t}^{jk}\, dt. \tag{3}$$

In particular, the time spent alive, if alive at age x, is the familiar:

$$T_x = \int_0^\infty I_{x,t}^{00}\, dt. \tag{4}$$

We note that T_x, the random future lifetime, is often taken as the starting point in defining a survival model. Its expected value is by definition $\mathrm{E}[T_x] = e_x$, and we see that this agrees with:

$$\mathrm{E}\left[\int_0^\infty I_{x,t}^{00}\, dt\right] = \int_0^\infty \mathrm{E}[I_{x,t}^{00}]\, dt = \int_0^\infty p_{x,t}^{00}\, dt \tag{5}$$

because clearly ${}_tp_x$ in traditional notation is the same as $p_{x,t}^{00}$ in our notation.

The advantage of this formulation is that it extends with no further work to a model defining two or more states of health, of which the simplest is illustrated in Figure 2.

Equations (2) to (5) remain equally valid (and also if we expand the model to several states of health), although the usefulness of random times between events is much less and we drop T_x and its analogues from now on. Now, Equation (4) defines the random time that will be spent in good health in future, and Equation (5) is the expected time that will be spent in good health in future. This is the simplest example of a quantity called 'health expectancy', which we will call HE for short.

The definition of HE is not complete until the precise meanings of 'healthy' and 'unhealthy' are fixed, and then the question of actually estimating HE depends on obtaining relevant data. Perhaps not surprisingly, the definitions of 'unhealthy' that are used in practice often follow those implied by readily available data, which can lead to problems when comparing HE estimates from different studies.

2.2 *Sullivan's Method*

If we start with the last expression in Equation (5) and make the trivial observation that:

$$\int_0^\infty p_{x,t}^{00}\, dt = \int_0^\infty \frac{p_{x,t}^{00}}{p_{x,t}^{00} + p_{x,t}^{01}} \left(p_{x,t}^{00} + p_{x,t}^{01}\right)\, dt \tag{6}$$

where:

(a) $p_{x,t}^{00} + p_{x,t}^{01}$ is the probability of being alive at time t (in other words, the traditional ${}_tp_x$); and

(b) $p_{x,t}^{00}/(p_{x,t}^{00} + p_{x,t}^{01})$ is the probability that someone alive at time t is in good health

then we have the basis of Sullivan's method (Sullivan, 1971) of estimating HE. The life table probabilities (a) above are fairly easily available at national and regional level; and the proportion in good health (b) above can be estimated from population-based health surveys or otherwise.

In practice, abridged life tables are often used (5-year age groups are common) with the estimated proportions in good health over the same age groups, and, in life table terms, the procedure is described as follows. Suppose the abridged life table has n-year age groups.

(a) The expected number of person-years lived between ages x and $x + n$ is ${}_nL_x$.

(b) Denote the estimated proportion unhealthy in age group x to $x + n$, also called the morbidity prevalence, π_x. Usually this is simply estimated as the ratio of the number classed as unhealthy to the number surveyed.

(c) The expected number of healthy person-years lived between ages x and $x + n$, may be denoted ${}_nHL_x$, and is ${}_nL_x(1 - \pi_x)$.

(d) The health expectancy (HE) at age x may be denoted he_x, by analogy with e_x, and is then $(\sum_{y \geq x} {}_nHL_y)/l_x$.

Older actuarial readers will realise that if $n = 1$ then π_x above differs from z_x, the central sickness rate, only in that the latter is conventionally expressed in units of weeks:

$$z_x = \frac{52.18 \int_0^1 f_{x+t} l_{x+t} dt}{\int_0^1 l_{x+t} dt} \tag{7}$$

where f_{x+t} is the proportion sick at age $x + t$ (see Hooker & Longley-Hook (1953)). Similarly, the definition of HE just given amounts to the expected present value of an annuity of 1 per annum, payable continuously while healthy, with interest of 0%.

2.3 *The Multi-state Method*

The chief drawback of Sullivan's method is the fact that it uses current morbidity prevalence rates (the π_x). The disadvantages of doing so have been rehearsed in several different but related fields, including the actuarial study of income protection (IP) insurance (CMIB, 1991) and the study by health economists of future long-term care costs (Bone *et al.*, 1995). Stated briefly, the transition intensities (the $\mu_{jk}(t)$) are the simple quantities that drive the model. The current prevalence rates are complicated outcomes of the past history of transition intensities. If, as is often realistic, patterns of health have changed in the past and may change in future, the transition intensities usually have the most direct interpretation. For example, new treatments of heart disease may reduce the incidence rates of heart attacks by 10%, but the effect on the prevalence of those who have had heart attacks depends on how this simple outcome works its way through the population over time. Therefore, transition intensities are much more suitable objects of study if the aim is to make long-term projections of population health.

The use of a multi-state method, therefore, has nothing to do with specifying the model within which HE is estimated — Sullivan's method was most conveniently described in a multi-state framework above — but with targeting the transition intensities as the parameters to be estimated. Given estimates of transition intensities, finding occupancy probabilities, prevalence rates, and expected values (including HE) is merely a matter of numerical computation.

A most important part of the model is still the definition of 'unhealthy'. If this concept remains tied to the response to a survey question, we would have to imagine being able to poll the respondent continuously, asking from moment to moment if they felt well or not. This is neither practical nor does it respond adequately to the criticism of HE estimates based on current prevalence rates given above. Rather, the multi-state method is viewed as an opportunity to change the definition of 'unhealthy' to one based on objective statistics, such as a record of illness or disability. Thus the most natural kind of study to use with the multi-state approach is a longitudinal survey. Unfortunately, these are expensive and time-consuming to carry out so are not common; the lack of longitudinal data means that few published studies have used this methodology, considerably fewer than those that have used Sullivan's method.

2.4 *Other Measures of Health Expectancy*

Equations (5) and (6) are obtained from the simplest possible model of good and bad health and a weighting system that attaches weight 1 to time spent in good health and weight 0 to time spent in bad health. An obvious extension is to define a larger number of progressive states between good health and death (we will cite some examples later). Suppose there are $m + 1$ such states, with state 0 representing good health and state m representing death. By assigning a score w_k to presence in state k, running from 1 when in good health ($w_0 = 1$) to 0 when dead ($w_m = 0$), we obtain a health-adjusted life expectation (HALE), also called a quality-adjusted life expectation (QALE):

$$\sum_{k=0}^{k=m} w_k \int_0^{\infty} p_{x,t}^{j,k}\, dt. \tag{8}$$

In fact in some schemes, states of health may be assigned a weight $w_k < 0$, representing 'worse than death'.

2.5 *Definitions of Health Status*

Here we summarise briefly the common notions of 'good' and 'bad' health, and associated terminology (and the many acronyms). These are closely tied to the forms of data that have been collected from time to time. The use of different definitions in different studies or in different countries clearly raises serious questions about comparability.

(a) The major methods of collecting health data are: (1) by survey questionnaire; and (2) from registries of disease incidence, hospitalisations, and so on.

(b) An example of health questions in a survey is the following, from the General Household Survey (GHS) in Great Britain:

> (a) "Over the last 12 months would you say your health has on the whole been good, fairly good or not good?
> (b) Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time or that is likely to affect you over a period of time. If yes:
> (1) What is the matter with you?
> (2) Does this illness or disability (Do any of these illnesses or disabilities) limit your activities in any way?"

Questions (a) and (b) capture different measures of health status. Question (a) asks how individuals feel about their general health; a person is normally regarded as healthy if the response is 'good' or 'fairly good'. It measures self-assessed health (SAH). Question (b) establishes the presence or absence of a long-standing illness (LI) and, if one exists, whether it is limiting (of activities) or not; in other words the presence or absence of a limiting long-term illness (LLI).

(c) Another, arguably more objective, measure of disability is independence in respect of activities of daily living (ADLs). A typical list of ADLs might be that recommended by the Association of British Insurers for use in connection with long-term care insurance, namely: washing, dressing, mobility, toiletting, feeding and transferring. Dependence in any one of these, meaning inability to perform it without some degree of help, would be elicited by survey questions. However, the apparently greater objectivity of this measure is largely lost when comparing HE estimates, because there are many different lists of ADLs, and variations in questions eliciting information about them. It seems to be common in studies of HE to regard dependence in just one ADL as defining poor health, whereas studies of long-term care costs typically use dependence in two or more ADLs as a threshold, and long-term care insurance policies may use dependence in three or more ADLs as a criterion for claiming the full sum assured.

(d) Yet another measure is aimed at cognitive impairment, as measured by scores on standard tests such as the Mini-Mental State Examination (MMSE), in contrast with functional impairment measured by ADLs.

(e) Almost any measure of health that can be devised and measured gives rise to a form of HE, which of itself is a broad rather than specific term. Robine *et al.* (1995) classified various definitions in the literature including, from the International Classification of Diseases (ICD), disease-free life expectancy and dementia-free life expectancy; and, from the International Classification of Impairments, Disabilities and Handicaps (ICIDH), impairment-free life expectancy, disability-free life expectancy, and handicap-free life expectancy. This research on harmonisation helped pave the way for the first publication of HE estimates for all 191 WHO member countries in 2000. This was based on disability-adjusted life expectancy where different health states are weighted on a scale of 0 (dead) to 1 (full health). Full details are in Mathers *et al.* (2000a, 2000b).

(f) HE based on SAH or LLI or ADL questions are examples of 'disability-free life expectancy' (DFLE). It remains the most common concept of HE in use today.

For convenience, we list below the abbreviations in common use, that we will use freely.

ADL	Activity of daily living
DFLE	Disability-free life expectancy
HALE	Health-adjusted life expectancy (Section 2.4)
HE	Health expectancy
LE	Life Expectancy
LI	Long-term illness
LLI	Limiting long-term illness
MMSE	Mini-mental state examination (measuring cognitive impairment)
QALE	Quality-adjusted life expectancy (Section 2.4)
SAH	Self-assessed health.

2.6 *Communal Adjustments*

Many health surveys (including the GHS) sample only the population of private households or dwellers therein. If so, they exclude the population of persons living in communal establishments such as nursing homes, psychiatric hospitals and the like. We should expect the prevalence of morbidity in such institutions to differ from that in respect of private households, therefore a 'communal adjustment' is sometimes made. This requires the numbers living in each type of accommodation to be estimated, separate estimates of morbidity prevalences made, and the two results to be combined into an appropriate weighted average HE measure.

If this proves impractical, perhaps because of data limitations, the use of the morbidity prevalences found in the survey will slightly overstate HE in the whole population. The effect is likely to be small — in respect of Scotland, Clark *et al.* (2004) estimated it to be 0.3 years (males) and 0.2 years (females), at birth and at age 65 — but it is another hindrance to comparability.

2.7 *Comparing Different Health Expectancy Studies*

The life table approach (Sullivan's method) appears to allow easy comparison of HE estimates between genders and socioeconomic groups as well as countries (Jagger, 1997). In practice this may not be so because of the different definitions that may be used, see Section 2.5. Buratta & Egidi (2003) identified methods of data collection (mainly interviews and registry data) as a second obstacle to comparability. At a detailed level, interview techniques and protocols can make a difference, for example in respect of survey size, sample structure, replacement procedures for non-responses, reference period, timing of interview, correction procedures for missing and inconsistent responses, and mode of interview.

Furthermore, Murray & Chen (1992) and Murray & Lopez (1996) reported significant cross-cultural differences between self-reported and observed disability and poor health. This was corroborated by the World Health Organisation (WHO) which identified severe limitations in the comparability of self-reported health status data from different populations, even when identical instruments and methods are used. This is particularly troublesome because we might expect that results from England and Scotland would be directly comparable if the same health survey (GHS) were used. The same might be hoped for the European countries which participate in the European Community Household Panel. If this is not the case, differences will arise that will be very difficult to measure and rectify.

3. Published Estimates I: Scotland

In this section we will describe the HE estimates that have recently become available for Scotland. Full details can be found in Clark *et al.* (2004). In Sections 4 to 7 we compare these with estimates — official, national, sub-national and otherwise — in respect of the United Kingdom and Europe. The thorny issue of comparability means we have to pay attention to the details of the methodologies.

3.1 *Official Health Expectancy Estimates*

The official HE estimates for Great Britain are published annually by the ONS, which uses the methodology described by Kelly *et al.* (2000), namely Sullivan's method applied to abridged (5-year age groups) national life tables from GAD, with a communal adjustment that will be described in Section 4. Morbidity prevalence rates were taken from appropriate responses the health questions asked in the GHS (quoted in Section 2.5(b)). The GHS samples approximately 25,000 private residents each year.

While question (b) was asked of everyone living in a household, question (a) was asked only of the head of the household, who had to be at least 16 years old. Hence, an age group of 16–19 was constructed for SAH instead of the 15–19 age group in the LLI. It was assumed that the morbidity prevalence for ages 0–15 was the same as that observed for ages 16–19.

Since 2004, separate official HE estimates have been available for Scotland and England. The latter are provided by the ONS, the former were produced by Clark *et al.* (2004) using the same methods (and same source of morbidity data) but making no communal adjustment, and were published by the ISD. The significance of this omission depends

Table 1: Official estimates of Health Expectancy for Scotland. Source: Clark *et al.* (2004). For convenience, estimates for 1999–2000 based on the Scottish Health Survey are also shown.

	At Birth						At Age 65					
	LE		HE (LLI)		HE (SAH)		LE		HE (LLI)		HE (SAH)	
Year	M	F	M	F	M	F	M	F	M	F	M	F
1980	68.7	75.1	57.9	61.0	62.6	65.9	12.1	16.1	7.8	8.7	10.0	12.1
1981	69.1	75.4	58.4	60.6	62.8	67.0	12.3	16.1	7.9	8.8	9.5	12.8
1982	69.3	75.3	57.5	60.5	63.7	66.2	12.3	15.9	7.2	7.9	9.6	11.8
1983	69.6	75.7	57.1	61.5	64.0	66.5	12.5	16.2	7.3	8.8	10.3	12.3
1984	69.9	75.9	58.3	61.1	63.7	65.2	12.5	16.6	6.9	9.2	9.9	12.1
1985	70.0	75.8	58.7	61.4	64.3	67.5	12.5	16.3	7.0	9.3	9.7	12.9
1986	70.1	76.3	57.6	60.8	64.2	67.7	12.6	16.4	6.3	8.6	9.6	12.1
1987	70.5	76.6	56.9	59.0	65.0	66.6	12.9	16.7	6.1	7.5	10.1	12.0
1988	70.3	76.6	56.0	59.8	64.6	68.2	13.0	16.7	7.3	8.3	10.4	12.5
1989	70.7	76.2	57.8	62.3	65.3	68.7	12.7	16.3	7.5	9.5	10.7	12.5
1990	71.2	77.1	57.3	61.1	65.7	68.0	13.2	17.0	8.5	9.7	11.3	13.6
1991	71.4	77.2	59.5	61.9	65.6	67.9	13.4	17.0	8.1	9.6	11.0	13.5
1992	71.6	77.4	57.7	61.3	66.0	67.6	13.4	17.1	7.9	9.6	11.4	13.3
1993	71.4	76.9	56.0	59.7	64.4	68.1	13.1	16.6	7.2	9.0	10.4	13.2
1994	72.1	77.7	58.2	60.5	64.6	67.5	13.7	17.3	8.3	9.4	10.8	13.3
1995	72.1	77.7	59.6	60.1	64.7	67.8	13.7	17.2	8.8	8.9	10.9	12.3
1996	72.1	77.9	57.7	60.0	65.7	69.1	13.9	17.5	7.5	9.6	11.4	13.7
1997	..	..	..	..	..	..	..	..	..	..	..	..
1998	72.6	78.2	60.1	61.1	65.2	68.2	14.3	17.6	9.6	9.9	11.4	14.7
1999	..	..	..	..	..	..	..	..	..	..	..	..
2000	73.3	78.7	58.9	62.6	65.3	67.3	14.8	17.9	9.3	9.6	11.3	12.2
SHoS	73.0	78.4	53.8	56.9	64.3	66.7	14.5	17.6	7.6	8.8	11.3	13.1

largely on the extent to which disability rates within communal establishments vary from those of the general population. Using 2001 census data, Clark *et al.* (2004) showed that the impact was very small; by excluding the communal adjustment, HE estimates both at birth and at age 65 were overstated by 0.3 years and 0.2 years for males and females, respectively. See Table 1 for the results for Scotland.

Perhaps the most striking outcome is that for males, LE at birth has increased by 4.6 years while HE based on LLI has hardly changed at all. If this is truly representative then it implies a marked expansion of morbidity. However, this is not seen to the same extent for HE (SAH), or for men age 65, or for women.

3.2 *Estimates Based on the Scottish Household Survey*

Clark *et al.* (2004) also estimated HE for Scotland for 2000 using the Scottish Household Survey (SHoS). This asked the following question about LLI:

Table 2: Estimates of HE at age 65 for Scotland based on independence in ADLs from the GHS. Source: Clark *et al.* (2004).

Year	LE		DFLE	
Year	M	F	M	F
1980	12.1	16.1	11.6	14.6
1985	12.5	16.3	11.6	14.6
1994	13.7	17.3	12.6	15.0
1996	13.9	17.5	12.0	14.8
1998	14.3	17.6	12.6	16.0

> "whether each of the people in the household has any longstanding illness, health problem or disability that limits your/their activity or the kind of work that you/they can do? By disability as opposed to ill-health, I mean a physical or mental impairment, which has a substantial and long-term adverse effect on their ability to carry out normal day to day activities".

The SAH question in the SHoS is identical to that asked on the GHS: as usual responses of 'good' or 'fairly good' are classified as healthy. The results are also shown in Table 1. Comparison with estimates based on the official methodology shows that the results are reasonably close for HE based on SAH, but alarmingly different for HE based on LLI. This implies that people report more LLIs under SHoS than under GHS.

3.3 *Estimates Based on Activities of Daily Living*

HE based on independence in ADLs has also been estimated for Scotland, using the GHS (Clark *et al.* (2004), see Table 2).

3.4 *Sub-National Health Expectancy Estimates*

Clark *et al.* (2004) also used the SHoS in three analyses of HE at a disaggregated level. Two looked for geographical variation, and one for socio-economic differences.

(a) LE and HE were estimated for 1999–2000 in respect of each of the 15 NHS Health Boards in Scotland, see Table 3. This showed some strikingly large variations. Table 3 shows the differences between the best and worst regions under each measure. Those for HE greatly exceed those for LE, in some cases being nearly double. Greater Glasgow is worst under 8 measures, its ex-industrial neighbour Lanarkshire under 3, and they share one. The differences, especially of HE at birth, dwarf the improvements in national HE achieved over the preceding 20 years (Table 1).

(b) A similar pattern was revealed by estimates in respect of the 32 Local Council Areas (LCAs), see Table 4. The differences were slightly greater, but Glasgow City and North Lanarkshire between them were worst or worst equal under 11 measures (Inverclyde accounting for male HE (LLI) at age 65).

(c) The socioeconomic study estimated HE by area deprivation for Scotland, with mortality data from the 2001 census. We describe this more fully in Section 7, where it can be compared with a similar study in England.

Table 3: Life and health expectancy estimates for Scottish NHS Boards, 1999–2000. Source: Clark *et al.* (2004).

	At Birth						At Age 65					
	LE		HE (LLI)		HE (SAH)		LE		HE (LLI)		HE (SAH)	
NHS Board	M	F	M	F	M	F	M	F	M	F	M	F
Argyll and Clyde	71.5	77.7	52.4	56.1	62.6	65.6	14.1	17.3	6.9	8.8	11.1	12.7
Ayrshire and Arran	73.2	77.6	51.1	54.8	62.3	66.3	14.5	17.2	6.8	8.1	10.7	13.0
Borders	75.2	80.0	55.4	61.5	68.3	70.8	15.9	18.6	8.3	10.0	12.2	15.1
Dumfries and Galloway	75.0	79.4	55.5	57.5	68.1	69.2	15.5	18.4	8.0	8.9	12.6	14.0
Fife	74.3	79.6	54.1	56.8	65.9	66.1	14.9	18.2	7.5	8.6	11.5	13.9
Forth Valley	73.7	78.7	53.5	57.3	65.1	65.6	14.5	17.5	7.4	9.1	10.7	13.1
Grampian	74.6	79.5	57.1	59.1	66.2	70.5	15.3	18.1	8.5	9.4	12.3	13.9
Greater Glasgow	70.4	77.0	49.9	53.9	60.3	63.3	13.6	17.0	6.7	7.8	10.0	11.7
Highland	72.9	79.4	54.4	57.9	66.1	69.0	14.7	18.5	8.1	9.1	12.8	13.7
Lanarkshire	72.3	77.7	50.3	53.3	60.6	63.5	13.7	17.0	6.8	8.0	9.5	11.3
Lothian	73.8	78.8	55.6	59.0	66.6	69.3	14.8	17.9	8.0	9.5	12.0	14.2
Orkney	74.2	82.2	61.3	65.0	70.6	71.6	15.0	20.4	10.0	11.7	13.5	15.7
Shetland	75.4	81.8	59.0	61.1	71.1	71.6	15.4	19.7	9.6	10.8	14.0	13.8
Tayside	73.8	79.2	57.1	59.6	65.6	65.9	15.1	18.1	8.6	9.9	12.4	14.5
Western Isles	72.5	80.1	57.3	62.0	66.6	70.4	13.8	18.7	7.6	10.6	11.6	13.5
Best − Worst	5.0	5.2	11.4	11.7	10.8	8.3	2.3	3.4	3.3	3.9	4.5	4.4
Scotland	73.0	78.4	53.8	57.0	64.3	66.8	14.5	17.6	7.6	8.9	11.3	13.2

Table 4: Life and health expectancy estimates for Scottish Local Council Areas, 1999–2000. Source: Clark *et al.* (2004).

	At Birth						At Age 65					
	LE		HE (LLI)		HE (SAH)		LE		HE (LLI)		HE (SAH)	
Local Council Area	M	F	M	F	M	F	M	F	M	F	M	F
Aberdeen City	73.6	78.9	55.6	57.3	64.5	70.3	15.0	17.7	7.4	8.5	11.1	13.2
Aberdeenshire	75.5	80.2	58.2	60.7	65.1	71.6	15.8	18.6	9.7	9.9	12.9	14.4
Angus	74.6	78.4	57.3	58.3	68.4	62.7	15.5	17.9	8.8	9.1	12.1	12.1
Argyll and Bute	73.4	78.8	56.4	60.9	64.8	69.8	15.3	18.1	9.1	9.6	12.0	14.9
Clackmannanshire	73.1	78.4	51.6	55.5	63.1	62.7	14.1	17.7	6.3	8.3	11.0	12.2
Dumfries and Galloway	75.0	79.4	55.4	57.5	68.1	69.5	15.5	18.4	7.9	9.0	12.7	14.3
Dundee City	71.7	78.3	55.4	57.8	60.6	64.7	14.4	17.8	7.8	9.6	11.9	14.5
East Ayrshire	72.7	76.4	46.8	52.1	57.8	66.1	14.0	16.5	6.0	7.4	11.0	12.5
East Dunbartonshire	76.2	79.9	56.5	57.8	69.0	68.8	15.8	18.3	7.1	7.1	12.9	12.1
East Lothian	75.1	79.3	54.7	59.7	67.7	71.4	15.5	17.9	7.6	9.7	11.1	13.9
East Renfrewshire	76.1	80.8	58.5	61.0	68.9	68.9	15.8	19.0	9.2	10.1	12.0	14.1
Edinburgh City	73.8	79.0	57.5	60.6	67.4	70.7	15.0	18.4	8.8	10.3	12.1	15.4
Eilean Star	72.5	80.1	57.5	62.4	66.5	70.6	13.8	18.7	7.6	10.7	11.4	13.7
Falkirk	73.3	78.3	51.3	54.8	65.2	64.4	14.3	17.4	6.0	8.7	10.5	12.8
Fife	74.3	79.6	54.1	56.7	65.9	66.1	14.9	18.2	7.5	8.6	11.6	13.8
Glasgow City	68.5	75.8	46.7	51.5	57.3	60.8	12.9	16.5	6.4	7.8	9.1	11.0
Highland	72.9	79.4	54.2	57.9	66.2	68.9	14.7	18.5	8.1	9.1	12.9	13.7
Inverclyde	70.1	77.2	50.5	53.0	61.0	65.4	13.7	17.2	5.5	8.0	10.2	13.3
Midlothain	74.2	79.0	54.0	56.9	65.5	66.3	14.9	17.7	6.6	7.8	13.1	13.0
Moray	74.6	79.1	57.3	59.0	67.4	68.3	15.1	18.0	8.2	10.3	13.0	13.4
North Ayrshire	72.8	77.9	52.6	56.3	63.1	64.4	14.5	17.2	6.6	7.9	9.2	13.2
North Lanarkshire	71.7	77.5	46.8	50.0	59.5	61.0	13.4	16.9	5.9	7.0	9.4	10.5
Orkney Islands	74.2	82.2	61.2	64.9	70.8	71.8	15.0	20.4	10.0	11.8	13.7	15.9
Perth and Kinross	75.3	80.8	58.5	62.5	68.6	69.1	15.6	18.6	9.1	11.1	13.2	16.0
Renfrewshire	71.0	77.6	53.2	57.0	63.8	63.7	13.8	17.0	7.0	8.9	10.5	11.3
Scottish Borders	75.2	80.0	55.1	61.2	68.3	70.7	15.9	18.6	8.2	10.0	12.2	15.1
Sheltand Islands	75.4	81.8	58.9	60.8	71.4	71.4	15.4	19.7	9.6	10.5	14.4	13.6
South Ayrshire	74.4	78.4	53.6	55.6	64.9	68.6	15.2	17.9	7.8	8.9	11.5	13.2
South Lanarkshire	73.0	77.7	53.8	55.6	62.0	66.2	13.9	17.2	7.0	8.1	9.5	12.2
Stirling	74.7	79.6	57.5	62.1	66.3	69.8	15.2	17.7	9.5	10.4	11.1	14.1
West Dunbartonshire	70.7	77.1	48.3	55.5	61.0	67.2	13.7	17.0	6.2	8.9	11.7	12.6
West Lothian	72.8	77.5	51.6	54.5	65.6	65.5	13.7	16.5	7.4	7.5	12.1	10.9
Best − Worst	7.7	6.4	14.5	14.9	14.1	11.0	3.0	3.9	4.5	4.8	5.3	5.5
Scotland	73.0	78.4	53.8	56.9	64.3	66.7	14.5	17.6	7.6	8.8	11.3	13.1

4. Published Estimates II: Official Estimates in England and Great Britain

Great Britain comprises the countries of England, Wales and Scotland. Most of the available estimates are for Great Britain as a whole, although they have often been attributed to England and Wales by authors. HE estimates are now available for England and Scotland separately, but not for Wales. Official HE estimates for England alone were first produced in 2004. Note that they are presented as a three-year moving average reported as applying to the central year[1].

The official HE estimates for Great Britain and England include a communal adjustment, currently based on the 2001 census. Morbidity prevalence was calculated from the responses to the relevant health question[2] and the enumeration of persons living in communal establishments. This rate was applied to the (estimated) numbers of people living in communal establishments, in respect of both SAH and LLI measures even though it is based on the presence of a LLI.

Table 5 shows, not the absolute values of the LE and HE estimates for England, but the difference between the English and Scottish estimates, for easier comparison. (In those years in which direct comparisons cannot be made, we do show the absolute values for completeness.) Table 6 shows the differences between the estimates for Great Britain and for Scotland. Not surprisingly, the general patterns in both tables are similar.

Scotland's mortality is consistently above England's, as is well known, but its morbidity is not. However, the differences between the HE estimates in the two countries vary considerably from year to year, which is probably just sampling variance in the GHS from year to year (see Section 6.1 for further comment on this).

The ratio of health expectancy to life expectancy (HE/LE) for short is often used to compare studies. Higher values indicate more healthy years and a relatively shorter decline; rising values indicate compression of morbidity, falling values indicate expansion. Table 7 shows the ratio:

$$\frac{\text{HE/LE for Scotland}}{\text{HE/LE for England}}$$

for those years when the comparison can be made. Perhaps surprisingly, it tends to exceed 1, especially for women and at age 65, indicating the opposite of what might usually be assumed.

[1] With a few exceptions: no survey was conducted in 1997 or 1999, so estimates for 1997 are based on 1996 and 1998, while estimates for 1999 are based on 1998 and 2000.

[2] The health question in the 2001 census was: "Does the person have any long term illness, health problem or handicap which limits his/her daily activities or the work he/she can do? Include problems which are due to old age"

Table 5: Official Estimates of Health Expectancy for England. For convenient comparison the table shows the differences (HE England) *minus* (HE Scotland), except in 1997, 1999 and 2001 when just (HE England) is shown, in italics (similarly for LE). Source: Office for National Statistics and Government Actuary's Department.

	At Birth						At Age 65					
	LE		HE (LLI)		HE (SAH)		LE		HE (LLI)		HE (SAH)	
Year	M	F	M	F	M	F	M	F	M	F	M	F
1981	1.98	1.64	−0.06	0.93	1.92	−0.02	0.77	0.94	−0.23	−0.19	0.59	−0.80
1982	2.02	1.96	1.12	0.51	1.31	1.12	0.85	1.24	0.41	0.71	0.50	0.24
1983	1.99	1.78	1.64	−0.21	1.27	1.22	0.78	1.07	0.21	−0.03	−0.16	−0.17
1984	1.89	1.71	0.50	0.52	1.64	2.44	0.84	0.72	0.71	−0.34	0.28	0.00
1985	1.97	1.95	0.15	0.22	1.29	0.44	0.94	1.09	0.68	−0.4	0.70	−0.64
1986	2.05	1.58	0.71	0.02	1.39	0.16	0.94	1.08	1.11	0.08	0.77	0.24
1987	1.89	1.50	1.30	1.44	0.68	1.42	0.83	0.94	1.26	1.01	0.36	0.39
1988	2.35	1.66	2.59	1.26	1.33	−0.19	0.88	1.02	0.31	0.44	0.21	−0.19
1989	2.15	2.23	1.10	−0.94	0.84	−0.42	1.29	1.51	0.5	−0.53	0.20	0.06
1990	1.88	1.51	2.02	0.82	0.64	0.46	0.90	0.87	−0.44	−0.40	−0.33	−0.82
1991	1.97	1.68	−0.07	−0.06	0.72	0.96	0.85	1.02	−0.14	−0.20	−0.12	−0.38
1992	1.99	1.58	1.96	0.58	0.67	1.24	0.92	0.91	0.09	−0.09	−0.52	−0.13
1993	2.51	2.32	3.43	1.99	2.21	0.78	1.40	1.56	0.94	0.54	0.62	0.00
1994	1.96	1.60	1.23	1.24	1.88	1.20	0.88	0.88	0.17	0.19	0.32	−0.26
1995	2.21	1.80	−0.43	1.46	1.98	1.10	1.08	1.13	−0.35	0.74	0.50	0.86
1996	2.40	1.69	..	..	..	..	1.03	0.87	..	..	..	..
1997	*74.76*	*79.76*	*59.21*	*60.79*	*67.33*	*69.00*	*15.14*	*18.49*	*8.40*	*9.50*	*11.86*	*13.25*
1998	2.39	1.69	..	..	..	..	1.01	0.98	..	..	..	..
1999	*75.28*	*80.10*	*60.31*	*62.59*	*66.87*	*69.19*	*15.53*	*18.76*	*8.84*	*10.04*	*11.66*	*13.26*
2000	2.32	1.64	..	..	..	..	0.99	1.07	..	..	..	..
2001	*75.97*	*80.60*	*60.84*	*62.86*	*67.31*	*69.04*	*16.06*	*19.17*	*8.94*	*10.22*	*11.72*	*13.33*

Table 6: Official Estimates of Health Expectancy for Great Britain. For convenient comparison the table shows the differences (HE Great Britain) *minus* (HE Scotland), except in 1997, 1999 and 2001 when just (HE Great Britain) is shown, in italics (similarly for LE). Source: Office for National Statistics and Government Actuary's Department.

	At Birth						At Age 65					
	LE		HE (LLI)		HE (SAH)		LE		HE (LLI)		HE (SAH)	
Year	M	F	M	F	M	F	M	F	M	F	M	F
1981	1.76	1.44	−0.29	0.81	1.63	−0.26	0.67	0.82	−0.33	−0.30	0.44	−0.92
1982	1.80	1.75	0.78	0.31	1.03	0.82	0.75	1.11	0.26	0.58	0.36	0.12
1983	1.78	1.57	1.26	−0.49	0.95	0.78	0.68	0.95	0.04	−0.16	−0.28	−0.30
1984	1.67	1.51	0.19	0.23	1.32	2.07	0.74	0.61	0.53	−0.44	0.16	−0.10
1985	1.76	1.76	−0.1	−0.06	0.97	0.05	0.84	0.98	0.49	−0.51	0.51	−0.80
1986	1.83	1.40	0.49	−0.27	1.14	−0.16	0.85	0.96	0.97	−0.10	0.64	0.07
1987	1.68	1.33	1.03	1.16	0.43	1.12	0.73	0.82	1.14	0.84	0.22	0.19
1988	2.13	1.47	2.26	0.93	1.03	−0.38	0.77	0.90	0.21	0.30	0.09	−0.32
1989	1.94	2.05	0.75	−1.21	0.53	−0.59	1.18	1.38	0.42	−0.63	0.07	−0.07
1990	1.67	1.32	1.68	0.53	0.36	0.28	0.78	0.75	−0.54	−0.52	−0.44	−0.93
1991	1.77	1.50	−0.37	−0.32	0.54	0.67	0.75	0.91	−0.2	−0.32	−0.16	−0.53
1992	1.77	1.39	1.57	0.35	0.40	0.96	0.81	0.79	−0.01	−0.21	−0.57	−0.28
1993	2.27	2.12	3.01	1.71	2.00	0.46	1.28	1.43	0.83	0.40	0.54	−0.16
1994	1.71	1.40	0.82	0.92	1.55	0.90	0.76	0.76	0.03	0.02	0.21	−0.45
1995	1.97	1.61	−0.74	1.09	1.63	0.81	0.97	1.01	−0.50	0.54	0.38	0.65
1996	2.15	1.49	..	..	..	..	0.91	0.75	..	..	..	..
1997	*74.51*	*79.57*	*58.81*	*60.42*	*66.85*	*68.68*	*15.02*	*18.38*	*8.26*	*9.31*	*11.69*	*13.12*
1998	2.14	1.49	..	..	..	..	0.88	0.86	..	..	..	..
1999	*75.02*	*79.61*	*60.27*	*62.23*	*66.53*	*68.82*	*15.40*	*18.63*	*8.79*	*9.80*	*11.53*	*13.08*
2000	2.04	1.44	..	..	..	..	0.87	0.93	..	..	..	..
2001	*75.70*	*80.40*	*60.50*	*62.72*	*67.02*	*68.83*	*15.94*	*19.03*	*8.81*	*10.07*	*11.62*	*13.17*

Table 7: Ratio of (HE/LE Scotland) / (HE/LE England) for 1981–1995, based on official extimates.

	At Birth				At Age 65			
	HE (LLI)		HE (SAH)		HE (LLI)		HE (SAH)	
Year	M	F	M	F	M	F	M	F
1981	1.030	1.006	0.998	1.022	1.094	1.082	1.000	1.129
1982	1.009	1.017	1.008	1.009	1.012	0.989	1.016	1.056
1983	1.000	1.027	1.009	1.005	1.033	1.070	1.079	1.081
1984	1.018	1.014	1.001	0.986	0.968	1.083	1.038	1.043
1985	1.026	1.022	1.008	1.019	0.980	1.115	1.003	1.123
1986	1.017	1.020	1.007	1.018	0.914	1.056	0.995	1.045
1987	1.004	0.995	1.016	0.998	0.882	0.931	1.028	1.023
1988	0.988	1.001	1.013	1.025	1.024	1.008	1.047	1.077
1989	1.011	1.045	1.017	1.036	1.033	1.157	1.081	1.087
1990	0.991	1.006	1.017	1.013	1.126	1.096	1.100	1.119
1991	1.029	1.023	1.016	1.008	1.082	1.083	1.075	1.091
1992	0.994	1.011	1.017	1.002	1.057	1.063	1.120	1.064
1993	0.975	0.997	1.001	1.019	0.979	1.032	1.045	1.094
1994	1.006	1.000	0.998	1.003	1.043	1.030	1.034	1.072
1995	1.038	0.999	1.000	1.007	1.124	0.984	1.032	0.996

5. Published Estimates III: Official Estimates in Europe

5.1 *Harmonisation of Health Expectancy Estimates in Europe*

Not surprisingly, different countries in Europe developed different instruments and definitions to measure health, so HE estimates could not be compared consistently. Suggestions for a common framework for monitoring health within the European Union date back to 1985 when DFLE was retained by the WHO as one of the indicators for measuring the regional objectives of *Health for All* in Europe. In the 1990s the European Commission set up a series of working parties on health data and information, and in June 1997 the European Community Health Monitoring Programme was established. Its objectives were to measure health status in the Community, to monitor health programmes and actions and to disseminate health information to allow comparisons and support national policies. It was agreed that the set of indicators would be built with a focus on the national experiences of the European countries but in conjunction with other initiatives such as WHO's ICD as far as possible. To this end, Euro-Reves was asked to set up a coherent set of indicators for the European Union. Euro-Reves identified the following five health domains: chronic morbidity; functional restriction; activity restriction; perceived health; and mental health (see Robine *et al.* (2000)).

Robine *et al.* (1998) published DFLE estimates for 12 countries in the EU using a common dataset. They were based on Wave 1 (1994) of the European Community Household Panel (ECHP) which asked the following health question:

> "Are you hampered in your daily activities by any chronic, physical or mental health problem, illness or disability?"

The possible responses were 'yes, severely', 'yes, to some extent' and 'no'. In the 1994 wave, 60,822 households (all private residences) were surveyed and 129,877 adults aged 16 and over were interviewed. Life tables were taken from Eurostat 1994 (except for Italy, for which only 1993 data were available). The morbidity prevalence of those living in communal establishments was taken to be the same as that of the general population, and morbidity prevalence of 1% was assumed below age 16.

Two levels of disability were analysed: DFLE based on all levels of disability ('yes, severely' and 'yes, to some extent'); and severe DFLE (SDFLE) based on 'yes, severely' only. General observations were that differences at birth between best and worst countries were 4 years for LE, 8 years for DFLE and 5 years for SDFLE (men and women) while at age 65 the differences in LE, DFLE and SDFLE were 3 years for women and 2 years for men. (Note that the report did not tabulate results so they are not presented here.)

Greek men had the highest LE and DFLE at birth, French women had the highest LE and Greek women the highest DFLE. France had the highest LE at age 65 and Luxembourg the highest DFLE. For men, Luxembourg had the highest SDFLE both at birth and at age 65, while for women Ireland and Spain were highest at birth and at age 65, respectively.

Following Robine *et al.* (1998), but with slightly different methodology, EuroStat now publishes DFLE for all EU countries. Tables 8 and 9 show estimates for 1995–2003 based on Waves 2–8 of the ECHP (2002 and 2003 are trend-based projections). Mortality data from NewCronos (MPROB) are used to create abridged life tables (5-year age groups). Morbidity prevalence at ages 16–19 was assumed to apply to ages 15–19 and similarly that of the oldest age group observed was assumed to apply at higher ages. Morbidity prevalence below age 16 was assumed to be half that at ages 16–19.

Italy, Spain, Belgium and Greece had the highest DFLE at birth for both men and women in 1995–2001. This differs from Robine *et al.* (1998) in that France fares less well. However, the gross disparities revealed by these studies — such as a difference of about 15 years between Italian and Finnish women — have raised questions about their reliability (see Shapiro (2005) for example). To put this in perspective, these differences between two entire countries are similar to the differences between the best and worst LCAs in Scotland, which are very much smaller (hence estimates should suffer more sampling error) and have known socioeconomic characteristics that arguably make differences plausible. One of the other major international comparative studies is that carried out by the WHO. Its estimates are not based on LLI questions but are of the HALE type so they are not directly comparable with the EuroStat estimates, but we show them anyway in the final columns of Tables 8 and 9 to make the point that they do not show the same large differences. So, although the EuroStat estimates are the most consistent there are, they should still be treated with some caution.

We have also shown the official estimates for Great Britain, England and Scotland, for the years when they are available, and the Scottish estimate for 2000 based on the SHoS.

In respect of men, Scotland and England join Finland, France and Portugal in a group

Table 8: Female DFLE at birth in Europe, 1995–2003. Italicised figures are estimated or provisional. Source: EuroStat. For comparison the official HE estimates based on the LLI question in the GHS, and the estimate based on the SHoS, are also shown. The final column shows the HLE estimate of the WHO (Source: 2004 World Health Report).

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	WHO 2002
Austria						68.0	68.5	*69.0*	*69.6*	73.5
Belgium	66.4	*68.5*	68.3	*65.4*	68.4	69.1	68.8	*69.0*	*69.2*	73.3
Denmark	60.7	61.1	*60.7*	*61.3*	60.8	61.9	60.4	*61.0*	*61.9*	71.1
Finland	..	57.7	57.6	58.3	57.4	*56.8*	56.9	*56.8*	*56.5*	73.5
France	62.4	62.5	63.1	62.8	63.3	*63.2*	63.3	*63.7*	*63.9*	74.7
Germany	64.3	64.5	*64.3*	*64.3*	*64.3*	*64.6*	*64.5*	*64.5*	*64.7*	74.0
Greece	*69.2*	69.6	68.7	68.3	69.4	68.2	68.8	*68.5*	*68.4*	72.9
Ireland	..	..	..	..	67.6	66.9	66.5	*65.9*	*65.4*	71.5
Italy	70.0	*70.5*	71.3	71.3	72.1	72.9	*73.0*	*73.9*	*74.4*	74.7
Netherlands	*62.1*	61.5	61.4	*61.1*	61.4	60.2	59.4	*59.3*	*58.8*	72.6
Portugal	63.1	60.5	60.4	61.1	60.7	62.2	62.7	*61.8*	*61.8*	71.1
Spain	67.7	68.4	68.2	68.2	69.5	69.3	*69.2*	*69.9*	*70.2*	75.3
Sweden	..	..	60.0	*61.3*	61.8	61.9	61.0	*61.9*	*62.2*	74.8
United Kingdom	*61.2*	*61.8*	*61.2*	*62.2*	*61.3*	*61.2*	*60.8*	*60.9*	*60.9*	72.1
Official GB	61.2	..	60.4	..	62.2	..	62.7	..	..	..
Official England	61.6	..	60.8	..	62.6	..	62.9	..	..	..
Official Scotland	60.1	60.0	..	61.1	..	62.6	..	..	..	..
SHoS (LLI)	..	..	..	..	..	57.0	..	..	..	..

Table 9: Male DFLE at birth in Europe, 1995–2003. Italicised figures are estimated or provisional. Source: EuroStat. For comparison the official HE estimates based on the LLI question in the GHS, and the estimate based on the SHoS, are also shown. The final column shows the HLE estimate of the WHO (Source: 2004 World Health Report).

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	WHO 2002
Austria	60.0	62.3	62.2	63.4	63.6	64.6	64.2	*65.6*	*66.2*	69.3
Belgium	63.3	*64.1*	66.5	63.3	66.0	65.7	66.6	*66.9*	*67.4*	68.9
Denmark	61.6	61.7	*61.6*	62.4	62.5	62.9	62.2	*62.8*	*63.0*	68.6
Finland	..	54.6	55.5	55.9	55.8	*56.3*	56.7	*57.0*	*57.3*	68.7
France	60.0	59.6	60.2	59.2	60.1	60.1	60.5	*60.4*	*60.6*	69.3
Germany	60.0	60.8	*61.9*	*62.1*	*62.3*	*63.2*	*64.1*	*64.4*	*65.0*	69.6
Greece	65.8	66.9	66.4	66.5	66.7	66.3	66.7	*66.7*	*66.7*	69.1
Ireland	63.2	64.0	63.2	64.0	63.9	63.3	63.3	*63.5*	*63.4*	68.1
Italy	66.7	67.4	68.0	67.9	68.7	69.7	69.8	*70.4*	*70.9*	70.7
Netherlands	61.1	62.1	62.5	61.9	61.6	61.4	61.9	*61.7*	*61.7*	69.7
Portugal	59.6	58.2	59.3	59.1	58.8	60.2	59.5	*59.7*	*59.8*	66.7
Spain	64.2	65.1	65.5	65.2	65.6	66.5	66.0	*66.6*	*66.8*	69.9
Sweden	..	..	62.1	61.7	62.0	63.1	61.9	*62.4*	*62.5*	71.9
United Kingdom	60.6	60.8	*60.9*	*60.8*	*61.2*	*61.3*	*61.1*	*61.4*	*61.5*	69.1
Official GB	58.9	..	58.8	..	60.3	..	60.5	..	..	..
Official England	59.2	..	59.2	..	60.3	..	60.8	..	..	..
Official Scotland	59.6	57.7	..	60.1	..	58.9	..	..	..	..
SHoS (LLI)	..	..	..	..	..	53.8	..	..	..	..

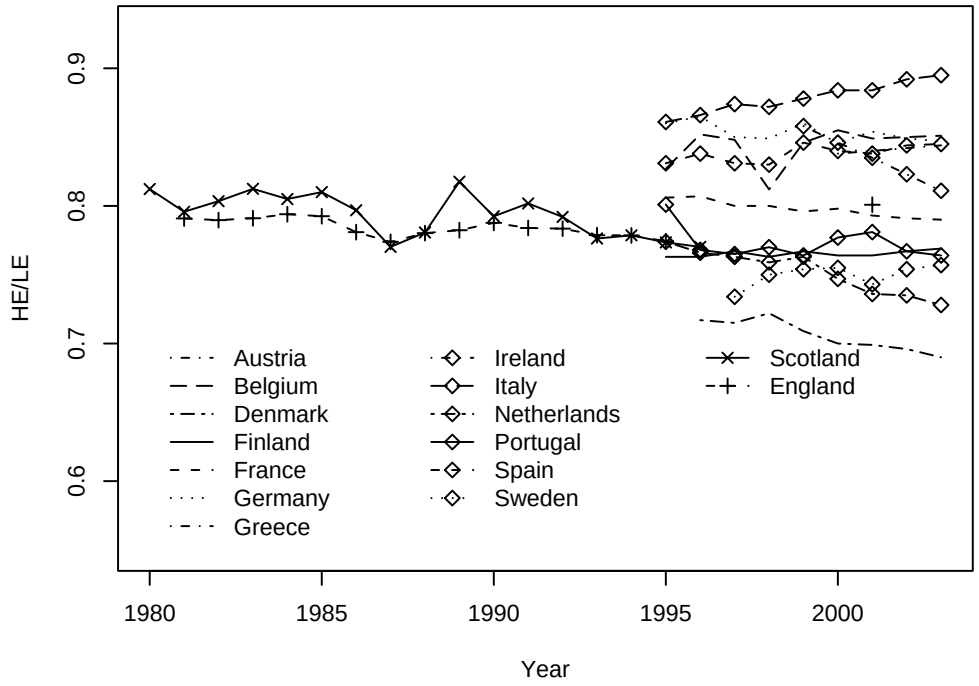

Figure 3: Ratio of HE/LE estimates for females in Scotland, England and thirteen European countries. UK figures are based on the official estimates, European figures are from EHEMU based on EuroStat estimates.

with the lowest DFLE, based on the official estimates but not those supplied to Eurostat. Among women, Denmark, the Netherlands and Sweden replace France in a somewhat larger group. Most conspicuously, however, the Scottish estimates for 2000 based on the SHoS are low, in fact below any estimates from five years before.

More recently the European Health Expectancy Monitoring Unit (EHEMU) has been set up, initially funded from 2004–7, with the aim of providing "... a central facility for the co-ordinated analysis, interpretation and dissemination of life and health expectancies to add the quality dimension to the quantity of life lived by the European populations." See the EHEMU website at `www.hs.le.ac.uk/reves/ehemutest/index.html`. In particular, Robine *et al.* (2004) reviewed the ECHP methodology and, in July and August 2005, EHEMU released detailed reports on each of the countries discussed above.

5.2 *Is There Compression or Expansion of Morbidity?*

Given a measure of HE, the trend in the ratio HE/LE (the proportion of total life lived in 'good health') is often taken as a measure of compression or expansion of morbidity, although it needs to be interpreted with caution: if HE/LE = 1.0 while LE plummeted this would probably not indicate successful health policy. Figure 3 shows this ratio for females, for 13 European countries since 1995, and for Scotland and England since 1980–81 and until 2000–01; Figure 4 shows the same for males.

First, note that Scotland and England are rather similar; neither has consistently higher HE/LE. Both appear to be trending slightly down until 1995, although the iso-

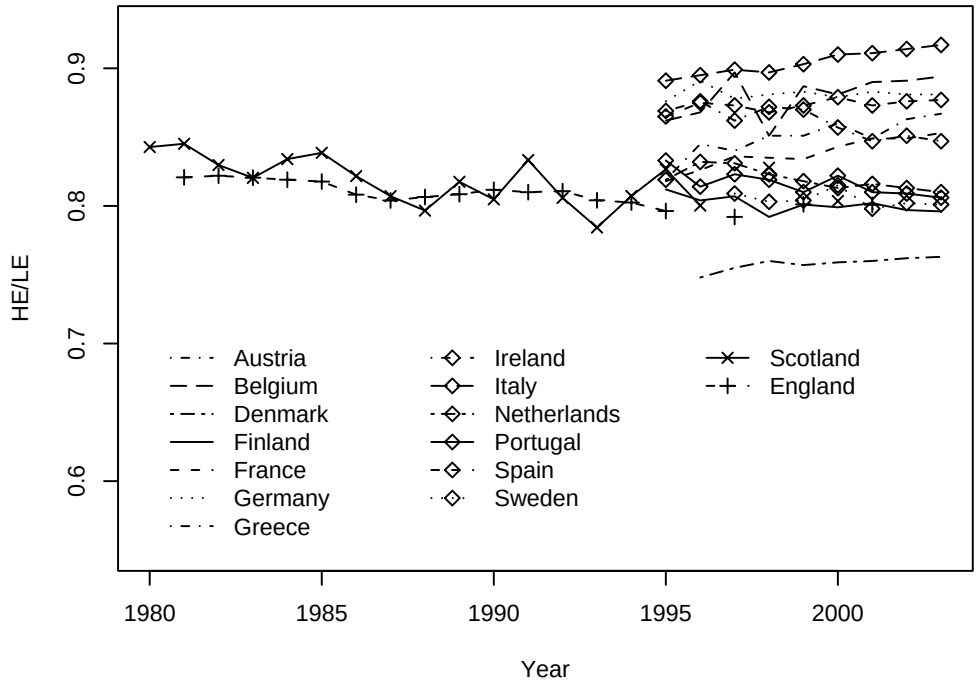

Figure 4: Ratio of HE/LE estimates for males in Scotland, England and thirteen European countries. UK figures are based on the official estimates, European figures are from EHEMU based on EuroStat estimates.

lated values reported since then are higher. If the unusually low ratios for Finland are discounted, Scotland and England have ratios among the lowest in Europe. Jagger (unpublished manuscript) studied the HE/LE ratio at age 65 and found some countries in which it had increased by 5% or more between 1995 and 2001, suggesting compression of morbidity, some in which in had declined by 5% or more, suggesting expansion of morbidity, and some in between[3]. In about the same period, based on official estimates, Scotland and England would in the last group.

6. Published Estimates IV: Other Studies in the United Kingdom

6.1 *Earlier Estimates Based On LLI Survey Responses*

The earliest HE estimates for England and Wales[4] were by Bebbington (1988), based on the LLI question in the GHS and OPCS mortality data. HE was estimated for 1976, 1981 and 1985. Bebbington (1991) added results for 1988, introducing a communal adjustment[5]. The estimates (see Table 10) showed that while LE improved over the period,

[3]There was no consistency between the results for men and for women.

[4]Strictly speaking, the estimates are applicable to Great Britain as a whole, but Bebbington (1988) assumed that they are equally applicable to England and Wales.

[5]Persons living in communal establishments such as geriatric wards, psychiatric hospitals, nursing homes, and institutions for younger handicapped persons were assumed all to be disabled, while people staying in other institutions such as hotels and acute hospital wards were assumed to share the population prevalence of morbidity.

Table 10: Early Estimates of HE for Great Britain based on the GHS Limiting Long-standing Illness question. For convenience the official Scottish estimates are also shown.

Year	Age	LE		Bebbington (1991)		Bone *et al.* (1995)		Bebbington & Darton (1996)		Official Scotland	
		M	F	M	F	M	F	M	F	M	F
1976	At Birth	70.0	76.1	58.3	62.0	58.3	62.0	58.4	62.1	..	..
	Age 65	12.5	16.6	7.1	8.6	7.1	8.6	7.1	8.7	..	..
1981	At Birth	71.1	77.1	58.7	60.9	58.7	61.0	58.7	61.0	58.4	61.0
	Age 65	13.1	17.1	7.9	8.5	7.9	8.5	7.9	8.6	7.9	8.8
1985	At Birth	71.9	77.7	58.8	61.9	58.8	61.9	58.9	61.9	58.7	61.4
	Age 65	13.4	17.3	7.9	9.2	7.8	9.2	7.9	9.3	7.0	9.3
1988	At Birth	72.4	78.1	58.5	61.2	58.5	61.2	58.5	61.2	56.0	59.8
	Age 65	13.7	17.6	7.6	8.8	7.5	8.7	7.6	8.8	7.3	8.3
1991	At Birth	73.2	78.7	..	..	59.9	63.0	59.9	62.8	59.5	61.9
	Age 65	14.2	17.9	..	..	7.9	9.8	8.0	10.1	8.1	9.6
1992	At Birth	73.7	79.2	..	..	59.7	61.9	59.7	61.9	57.7	61.3
	Age 65	14.5	18.3	..	..	7.9	9.5	7.9	9.5	7.9	9.6
1994	At Birth	74.2	79.6	..	..	..	..	59.2	62.2	59.4	61.7
	Age 65	14.8	18.6	..	..	..	..	8.5	9.8	8.5	9.6

HE was stable. Bebbington (1988) concluded that improved mortality has resulted in the expansion of morbidity.

Bone *et al.* (1995) extended the study to 1991 and 1992 (see Table 10) but used a different communal adjustment[6]. Taking the trends in LE and HLE together, morbidity expansion was less obvious, except for males age 65. However, by adding 1994 to the series (see Table 10), Bebbington & Darton (1996) concluded that the observed increase in LE was accounted for almost totally by years of ill-health. Note that they used yet another communal adjustment. It is clear that the different communal adjustments had a very small impact.

We have added the official Scottish estimates (based on LLI) to Table 10, for years for which they are available. The comparison does not strongly suggest that HE in Scotland is much lower or consistently lower than it is in England. The comparison with Table 5 is interesting. Roughly speaking, it happens that three out of the five years studied were those in which Scottish HE was relatively close to English HE, which seems to be the chance result of the sampling variability suggested by Table 5.

Bebbington (1992) estimated HE using data from the OPCS disability surveys. He argued that while these might be superior to estimates based on the GHS, the GHS has a strong appeal because it reveals long-term trends. The OPCS surveys sampled some 100,000 private and 2,000 communal residents throughout Great Britain in 1985–88. Over

[6]The 1991 census included, for the first time, the LLI question, allowing the morbidity prevalence of these persons in communal establishments to be found directly, then estimated indirectly for 1976, 1985, 1988 and 1992.

Table 11: Estimates of HE at age 65 for Great Britain based on the independence in ADLs from GHS.

Year	LE		Bone *et al.* (1995)		Bebbington & Darton (1996)		Scotland	
	M	F	M	F	M	F	M	F
1976	12.5	16.5	11.0	13.0	..	..	..	..
1980	12.9	16.9	11.8	15.0	11.6	14.4	11.6	14.6
1985	13.3	17.3	12.3	15.5	12.1	14.2	11.6	14.6
1991	14.3	18.1	14.3	16.9	..	..	..	..
1994	14.8	18.6	..	..	13.5	15.6	12.6	15.0

21,000 were identified as having disabilities, were interviewed, and the responses were classified from 1 to 10 using the ICIDH scale[7], 7 or over indicating severe disability. He found that as people age, the remaining number of years without disability falls rapidly. The DFLE at birth for men was 63.6 years without any disability and 70.0 years without severe disability out of a total LE of 71.7 years (women: 66.5 years and 74.5 years out of 77.5 years). He therefore emphasised the importance of the definition of disability when making comparisons with studies which use a single level of disability.

6.2 *National Estimates Based On Activities of Daily Living*

Bone *et al.* (1995) also estimated DFLE for persons aged 65 and over for 1976, 1980, 1985 and 1991 using a definition of disability based on the following ADL data taken from the GHS (except for 1976 when the Elderly Home Survey was used): bathing, getting out of bed, feeding, and going to the toilet. The communal adjustment was based on the UK Disability Surveys 1985–6. DFLE increased steadily for men and women, a trend corroborated by Bebbington & Darton (1996), see Table 11.

We have added the Scottish estimates of DFLE based on ADLs (Clark *et al.*, 2004, see also Table 2) to Table 11. There is no very consistent pattern, compared with those for England and Wales.

These HE estimates suggest compression of morbidity, contrary to those based on LLI. Bone *et al.* (1995) argued this may be related to increased awareness of ill-health coupled with improved diagnosis, causing persons to self-report a higher degree of sickness under the LLI measure.

6.3 *Estimates of Health-Adjusted Life Expectation*

HE estimates for Great Britain have mainly been based on questions asked in the GHS, which effectively dichotomise health status as 'good' or 'bad'. Bebbington (1992) used the OPCS disability surveys to rate health states by severity and estimate HALE,

[7]Introduced in 1980 by the WHO, the ICIDH scale goes beyond the ICD by categorising the consequences of disease. The following activities are covered: locomotion; reaching and stretching; dexterity; personal care; continence; seeing; hearing; communication; behaviour; intellectual functioning; consciousness; eating, drinking and digestion and disfigurement.

while Bebbington & Darton (1996) estimated QALEs, using the five-point EuroQol Scale[8] and the UK Omnibus Survey[9]. The results were significantly higher than estimates based on LLI, implying that the weights represented a less severe definition of morbidity.

6.4 *Health Expectancy Allowing for Cognitive Impairment*

MRC-CFAS[10] (2001) chose 15,000 persons aged 65 and over at random (80% of whom were successfully interviewed) to estimate HE based on functional, cognitive and physical health problems. Functional ability was based on a scale of 0 to 18 for ADLs, 11 and above indicating impairment. Cognitive impairment was based on a MMSE score of less than 18, while physical health problems were self-reported, excluding any related to cancer (not regarded as a risk factor for dementia). Men at age 65 could expect to live 83.1% of their remaining years with physical illness, but only 7.5% with functional impairment and 3.7% with cognitive impairment (women: 86.7%, 14.7% and 6.8%). Therefore, women can expect to live a much higher proportion of their lives with impairments of any kind than can men, but functional and cognitive impariments are confined to the last few years of life, given the nature of these illnesses.

6.5 *Estimates of Health Expectancy Based on Longitudinal Data*

Bone *et al.* (1995) made the first attempt at HE estimation using UK longitudinal data. They created a multi-state life table (Ledent, 1980; Rogers *et al.*, 1990) using the Nottingham Longitudinal Study of Activity and Aging[11] (NLSAA) and Melton Mowbray Aging Project[12] (MMAP) data for 1981, 1985 and 1988, and the following indicators of health status: mental impairment; vision and hearing impairment; urinary continence; physical disability and mobility impairment; self-perceived health; depression; and global health. The initial surveys distributed the subjects between initial states 'healthy' and 'unhealthy' for each indicator. Piecewise exponential regression models were fitted to age x and sex s to obtain smoothed transition rates:

$$\ln \mu^{ij}(s,x) = \alpha^{ij} + \beta^{ij}(x) + \gamma^{ij}(s). \tag{9}$$

[8]The EuroQol scale rates health status in respect of mobility, self care, usual activities, pain/discomfort and anxiety/depression.

[9]In the UK Omnibus Survey some 6,000 adults living in private households were asked about the five EuroQol qualities, with three response levels: 1 = no problems; 2 = some problems; and 3 = extreme problems or confined to bed.

[10]MRC-CFAS, (Medical Research Council Cognitive Function and Ageing Study) is a longitudinal study of the relationship between cognitive function, dementia and ageing. The six centres involved are Cambridgeshire, Gwynedd, Newcastle, Nottingham, Oxford and Liverpool, representing a mix of urban and rural areas. It is a two-wave (with waves two years apart), two-stage population prevalence survey with the initial sample of individuals aged 65 and over taken in 1991.

[11]The Nottingham Longitudinal Study of Activity and Aging consists of people living in the community, aged 65 and over, from Nottinghamshire FPC lists. 1,042 people were interviewed in 1985 and followed up in 1989 (response rate 88%).

[12]The Melton Mowbray Aging Project comprises two cross-sectional surveys and intermediate follow-up in the Latham General Health Practice in Melton Mowbray and surrounding areas. The first survey in 1981 included 1,203 people aged 65 and over. The second in 1988 included 1,579 persons aged 75, 440 of whom were survivors from the 1981 sample. At the intermediate follow-up in 1985, 602 out of 651 survivors age 75 and over were interviewed. Community and institutionalised persons were included.

While the authors reported the results for each definition of 'unhealthy', they drew no general conclusions. Instead, they suggested that "no longitudinal data of the right kind exist in this country (the UK) at the national level".

Sauvaget *et al.* (2001) updated Bone *et al.* (1995) using data from the Melton Mowbray Health Checks[13] and a multi-state life table method to calculate: (a) active life expectancy, based on independence in all the ADLs: mobility around the home; getting in and out of a chair and bed; feeding; dressing; bathing; and using the toilet; and (b) cognitive impairment-free life expectancy based on a score of 7 or less from the information/orientation subset of the Clifton Assessment Procedures of the Elderly.

The results were that a man age 75 could expect to spend 49% of his remaining life with an ADL impairment, but only 7.7% with cognitive impairment (women 71% and 6.6%, respectively). At older ages men are worse off; for men (women) the expected proportion of total LE with cognitive impairment is 14.5% (8.3%) at age 80, 20.5% (8.7%) at age 85 and 30.4% (11.1%) at age 90. This is the opposite of what might have been expected based on the MRC-CFAS study.

6.6 *Remark*

The studies mentioned above do not all have direct counterparts in Scotland — the comments by Bone *et al.* (1995) on the lack of suitable longitudinal data apply equally to Scotland and England — but we include them to illustrate how different studies of considerable size but with different methodologies can lead to conflicting results. Overall, the comparisons of national HE based on the official estimates in Scotland and England, and on the EuroStat estimates in the EU, are the most informative, not least because they come close to providing comparable chronological series.

7. Published Estimates V: Sub-National Estimates in the United Kingdom

We mentioned in Section 3.4 three disaggregated surveys of HE in Scotland by Clark *et al.* (2004); one by NHS Boards, one by Local Council Areas and one by deprivation index.

Bebbington (2003) found that only Canada, England and Wales, France and Spain actively produced sub-national estimates (all using Sullivan's method). He argued that migration might cause Sullivan's method to break down as healthy areas may tend to attract healthy migrants (possibly explaining the north/south divide in England).

Table 12 shows the results of the analysis of HE by area deprivation for England (Bajekal, 2005), and Table 13 shows the results of the previous analysis for Scotland based on the SHoS (Clark *et al.*, 2004).

(a) Bajekal (2005) calculated deprivation scores for the 8,595 electoral wards in England using 1991 Census data and the Carstairs & Morris (1991) deprivation index[14]. Wards were grouped into deciles in order of deprivation. Using these groupings, he estimated

[13]Health checks were introduced in 1991 as part of a UK requirement for all persons age 75 and over to be given an annual check-up.

[14]This index was developed in Scotland, and rates deprivation *via* the following indicators: households headed by an individual from Class IV or V; economically active men seeking work; absence of a car; and overcrowded accommodation.

HE for 1994–98 (to coincide with HSE data) with two definitions of 'healthy': (i) responses of 'very good' or 'good' on the five-point scale of SAH 1994–99, which he called HLE; and (ii) free of LLI from 1996–99 only, which he termed DFLE. The differences between the most and least deprived areas at birth were very large; for HLE, 16.9 years for men and 16.8 years for women, and for DFLE, 12.4 years and 9.9 years, respectively. These are grossly in excess of the corresponding differences in LE at birth (3 years for men and 3.2 years for women). However, this hides even more alarming facts. For example, in the most deprived wards, HLE at birth was about 22 years (men) and 26 years (women) less than total LE. The differences in HE at age 65 were much smaller.

(b) Clark *et al.* (2004) estimated HE by area deprivation for Scotland, also using the Carstairs & Morris (1991) index. Morbidity data was taken from the 2000 SHoS and mortality data from the 2001 census. They also used similar measures of health as Bajekal (2005), but grouped data into quintiles instead of deciles. Because of the different grouping, smaller differences were observed than in England. Specifically, the difference between the most and least deprived quintiles for LLI and SAH at birth was 13.0 years and 11.1 years, respectively, (females) and 14.6 years and 17.4 years (males).

Other studies relating to England are difficult to compare directly with Scotland, but they are of interest because they clearly show the difficulties that lack of consistent data definitions cause.

Bebbington (1993) was the first to quantify disparities in HE across regional boundaries in Britain, finding that a man born in south-east England could expect to live up to 5.3 more healthy years than one born in the north (based on the OPCS disability surveys). For women, the difference was 3.8 years.

The north/south divide was also observed by Bone *et al.* (1995) who undertook sub-national HE estimates by Standard Regions and Regional Health Authority (RHA) areas in England and Wales, using the LLI question in the 1991 census. They found that the difference in HE at birth between (regions) Wales and the South-East was as much as 6 years for men and 4.7 years for women. The differences were even greater in terms of RHA with Wales and Northern recording the lowest HE of 60.4 years for males and 64.7 and 64.8 years, respectively, for females. The highest HE was in South West Thames, 66.9 years for males and 70.0 years for females.

Bisset (2002) found, in National Health Service (NHS) regions in England and Wales, that: (i) the difference between LE and HE was increasing, suggesting an expansion of morbidity; and (ii) as in earlier studies, HE was lower in northern NHS regions than in those in the south. Similiar findings were observed at the RHA level.

Bebbington (1993) also defined three socioeconomic groups of men by grouping class I (professionals) with class II (employers and managers), class IIIN (skilled non-manual) with class IIIM (skilled manual), and class IV (semi-skilled) with class V (unskilled). Women were too hard to classify so were omitted. At age 20 the differences in HE between the top and bottom groups were 9 years (based on the LLI queston in the GHS) or 7 years (based on OPCS disability surveys).

Table 12: LE and HE estimates for Deprivation Deciles, England, 2000. Source: Bajekal (2005).

	At Birth						At Age 65					
	LE		HLE (1994–99)		DFLE (1996–99)		LE		HLE (1994–99)		DFLE (1996–99)	
Decile	M	F	M	F	M	F	M	F	M	F	M	F
10 - Most deprived	71.4	78.0	49.4	51.7	50.7	54.6	13.9	18.0	6.3	7.8	6.8	8.0
9	72.8	78.9	52.4	56.0	54.0	56.6	14.4	18.3	6.9	8.7	6.6	7.9
8	73.4	79.1	55.3	58.0	55.4	57.8	14.5	18.4	7.8	9.5	7.6	9.1
7	74.4	79.7	56.3	58.7	57.0	59.2	15.0	18.7	7.8	9.7	7.9	9.3
6	75.0	80.1	58.4	59.9	58.1	58.8	15.2	18.8	8.4	9.8	8.0	9.0
5	75.6	80.5	59.7	62.3	59.9	61.3	15.5	19.1	8.7	10.7	8.7	10.2
4	76.0	80.7	62.2	64.7	60.9	62.1	15.6	19.1	9.6	11.6	9.4	10.5
3	76.6	81.0	63.9	65.7	61.4	64.2	15.9	19.3	10.4	11.2	9.7	10.7
2	76.9	81.1	65.0	66.9	62.4	63.3	16.0	19.3	10.7	12.5	10.0	10.7
1 - Least deprived	77.4	81.2	66.2	68.5	63.1	64.6	16.2	19.1	11.0	12.5	9.5	11.0
England	75.0	80.0	59.1	61.4	58.4	60.4	15.2	18.8	8.8	10.4	8.5	9.7

Table 13: LE and HE estimates for Deprivation Quintiles, Scotland, 2000. Source: Clark et al (2004).

	At Birth						At Age 65					
	LE		HE (LLI)		HE (SAH)		LE		HE (LLI)		HE (SAH)	
Quintile	M	F	M	F	M	F	M	F	M	F	M	F
5 - Most deprived	69.1	76.4	47.8	51.2	55.9	61.6	13.6	17.2	6.5	7.8	9.7	11.6
4	72.5	77.9	50.6	54.6	62.8	64.9	14.6	17.6	6.8	8.3	10.7	12.1
3	73.8	79.2	53.6	56.4	64.6	68.0	15.0	18.3	7.6	8.9	11.6	13.7
2	75.5	80.6	58.8	61.5	68.8	70.8	16.0	18.9	8.8	9.6	12.9	15.0
1 - Least deprived	77.6	81.1	62.4	64.2	73.3	72.7	16.7	19.2	10.0	10.7	14.5	16.0

Melzer *et al.* (2000) tried to extend these results using the MRC-CFAS data, including women. They grouped classes III, IV and V together, and defined disability as the presence of mental or physical disability (based on ADLs) or both. They found that men in the upper socioeconomic groups had higher LE and DFLE, but that DFLE for women did not differ significantly between socioeconomic classes.

Methodological issues have also been exposed in these and other disaggregated studies. Bisset (2002) suggested that the main impediment to producing such estimates was the lack of sufficient morbidity data to produce reasonable confidence intervals, and recommended three solutions, namely: (i) increasing the width of the age intervals; (ii) increasing the number of years of data; or (iii) combining data for males and females[15]. Bajekal *et al.* (2002) followed this approach to compare estimates based that GHS with those based on the Health Survey for England (HSE), grouping GHS data for 1992–98 and HSE data for 1994–99, at national and RHA level. They used the SAH measure only. However, comparisons were hampered by inconsistencies; in particular, the HSE offered five responses to the SAH question while the GHS offered three (the Scottish Health Survey, considered in the next section, also offers five responses) and the GHS uses a reference period of twelve months but there is none in the HSE. As a result they defined 'good health' in three different ways, which included 75%, 88% and 94% of the relevant responses, and at least showed the resulting measures to be highly correlated[16].

8. The Scottish Health Survey

8.1 *Introduction*

The Scottish Health Survey (SHeS) is an initiative of the Scottish Executive and was undertaken by the Joint Health Survey Unit in order, *inter alia*, to provide data on Scottish health and to monitor trends in population health over time, and to enable the estimation of prevalence rates of specific conditions and comparisons of different subgroups. The first survey was in 1995, and the second in 1998, and the latter is relevant here. Information was gathered continuously between April 1998 and March 1999 using a combination of interviewer-administered questionnaires and nurse visits[17]. The results include information on demography, socioeconomic status and results from medical tests. The 1998 survey included 14,000 individuals age 2–74 years of whom 9,000 were age 16–74 years and were considered to be adults. The sample was taken from the Postal Address

[15]In her investigation of eight National Health Service (NHS) regions, she combined four years of data to create two separate epochs, 1992–5 and 1995–8. For her investigation at the Health Authority (HA) level, she formed one epoch, 1992–8, and combined males and females.

[16]At the national level, HE at birth was 73.0, 68.4 and 59.3 years moving from the least to most strict definitions of 'good health', and the corresponding differences in HE between the best and worst RHAs were 17 years, 12 years and 11 years, respectively; thus a stricter definition of 'good health' leads to a smaller difference in HE. Grouping the RHAs into quintiles confirmed the north/south divide found by other authors (except for inner-city London).

[17]There is no single survey date, but the records contain the dates upon which each person was interviewed. We will refer to 'survey date' in the following for convenience, but we actually use the exact interview date for each person. Thus we may be aggregating results for persons nominally the same age 'at the survey date', whose calendar ages may differ by up to a year.

File (PAF) where sample addresses were selected from 312 postal sectors, 26 each month during the 12-month survey period.

Our interest in the 1998 survey is in that the responses have been linked to some of the medical records of the participants, thus providing: (a) the survey responses, a snapshot in 1998–99; and (b) longitudinal health data. We will call it the 'linked data' (officially it is known as the SHeS-SMR data). To create it, responses of 8,305 of the adults surveyed were linked with their records of acute hospital admissions (SMR01), psychiatric admissions (SMR04), cancer registrations (SMR06) and deaths dating back to 1981 and up to March 2004[18]. Of the 8,305 adults available for linkage, 331 may have migrated from Scotland during the linkage period and were dropped, leaving 7,974 (3,507 males and 4,467 females). The work was carried out by ISD.

8.2 *Responses to the Health Questions*

We are particularly interested in two health questions in the 1998 SHeS, that may be used to estimate HE. The general health question (SAH) was as follows:

(a) "How is your health in general? Would you say it was:
  (1) very good
  (2) good
  (3) fair
  (4) bad
  (5) very bad."

This is not the same as the SAH question asked in the GHS and the SHoS; it offers five responses instead of three. We will see later that these differences are reflected in the HE estimates. However, the question is very close to that asked on the HSE in England. The responses are summarised in Table 14.

The question relating to the presence of one or more LLIs was as follows:

(a) "Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time or that is likely to trouble you over a period of time."
  (1) Yes
  (2) No
(b) "What (else) is the matter with you?", the answer to which could include up to six illnesses. Finally, respondents were asked,
(c) "Does this illness or disability limit your activities in any way?"
  (1) Yes
  (2) No
(d) "Do you have any other long-standing illness, disability or infirmity?"
  (1) Yes
  (2) No

Therefore a person is said to have a LLI if they answer 'yes' to parts (a) and (c) of the question. Table 15 summarises the numbers of persons with a LLI, those with non-limiting long-standing illness and those with no long-standing illnesses at all.

[18]Except SMR06 records, only up to December 2001.

Table 14: Responses to the general health question in the 1998 Scottish Health Survey.

	SAH=1,2		SAH=3		SAH=4,5		Total	
Age Group	Males	Females	Males	Females	Males	Females	Males	Females
16-19	128	141	30	24	0	0	158	165
20-24	158	230	20	35	3	6	181	271
25-29	254	314	37	43	7	8	298	365
30-34	291	400	62	65	13	19	366	484
35-39	322	403	57	65	9	16	388	484
40-44	286	334	52	58	20	22	358	414
45-49	238	270	58	72	21	28	317	370
50-54	230	319	54	86	28	33	312	438
55-59	203	226	81	76	39	48	323	350
60-64	170	229	77	108	42	31	289	368
65-69	168	256	84	103	27	42	279	401
70-74	129	212	78	108	31	37	238	357
Total	2,577	3,334	690	843	240	290	3,507	4,467

Table 15: Responses to the long-standing illness question in the 1998 Scottish Health Survey. Respondents may report more than one LI but duplicates have been removed, we show the numbers of people reporting at least one LI or LLI.

	LLI		No LLI		No LI		Total	
Age Group	Males	Females	Males	Females	Males	Females	Males	Females
16-19	8	16	26	31	124	118	158	165
20-24	20	33	24	31	137	207	181	271
25-29	37	48	54	41	207	276	298	365
30-34	65	92	56	64	245	328	366	484
35-39	54	91	66	69	267	324	387	484
40-44	73	85	58	56	227	272	358	413
45-49	79	113	55	59	183	198	317	370
50-54	90	142	59	67	163	228	312	437
55-59	124	141	54	67	145	142	323	350
60-64	134	140	53	87	102	139	289	366
65-69	118	162	57	79	104	160	279	401
70-74	110	163	54	79	74	115	238	357
Total	912	1,226	616	730	1,978	2,507	3,506	4,463

Table 16: Numbers of reported long-standing illnesses in the SheS, and the numbers of those reported to be limiting.

	Males		Females	
Disorder	LI	LLI	LI	LLI
Cancer	29	13	60	25
Diabetes (inc) hyperglycaemia	96	31	95	27
Other endocrine/metabolic	44	19	135	39
Mental illness/anxiety/depression/nerves	101	81	187	143
Other problems of nervous system	85	65	93	84
Poor hearing/deafness	56	25	41	20
Heart attack/angina	128	99	129	97
Hypertension/high blood pressure/blood pressure	130	30	190	47
Other heart problems	127	91	78	51
Bronchitis/emphysema	57	42	73	58
Asthma	154	55	242	108
Other respiratory complaints	57	38	67	38
Stomach ulcer/ulcer (nes)/abdominal hernia/rupture	76	32	79	32
Other digestive complaints	54	17	56	25
Complaints of bowel/colon	49	22	119	65
Arthritis/rheumatism/fibrositis	209	168	444	345
Back problems/slipped disc/spine/neck	217	158	223	172
Other problems of bones/joints/muscles	197	152	222	180
Skin complaints	72	16	90	31
Other	372	205	467	271

Parts (b) and (d) of the LLI question asked respondents what was wrong with them. Respondents could list more than one illness. Interviewers coded these responses using a list of 45 illnesses. After dropping invalid responses we were left with 5,400 LIs, reported by 3,484 people (about 1.6 illnesses per person) of which 3,217 were regarded as limiting.

Table 16 shows the diseases that account for the largest numbers of reported LIs, and for each of them the numbers that are reported as limiting[19]. Men suffered most from heart problems, hypertension, asthma, arthritis, back problems and problems of the bones, muscles and joints. Women were similar, but asthma and arthritis are much more problematic. The table also shows the extent to which persons find particular illnesses limiting. As expected, arthritis, back problems and other problems of bones, joint and muscles, and heart problems were considered more limiting than asthma or hypertension. Asthma is by far the commonest cause of a LI among young people.

8.3 *HE estimates*

Using the 1998 population and deaths for Scotland (the same as were used in estimates based on the GHS), HE estimates for Scotland were calculated using different definitions

[19]Respondents may report more than one LI, so the totals in Tables 15 and 16 will differ.

Table 17: Health expectancy estimates based on the 1998 Scottish Health Survey (SHeS), compared with the official estimates for 1998 and those based on the 2000 Scottish Household Survey (SHoS). The SHeS offered five responses to the SAH question while the SHoS offered three.

		At Birth		Age 65	
Study	HE Measure	M	F	M	F
Official	SAH	65.2	68.2	11.4	14.7
Official	LLI	60.1	61.1	9.6	9.9
SHoS	SAH	64.3	66.8	11.3	13.2
SHoS	LLI	53.8	57.0	7.6	8.9
SHeS	SAH 'good' = 1,2,3	68.7	74.1	12.6	15.7
SHeS	SAH 'good' = 1,2	54.3	59.4	8.0	10.6
SHes	LLI	57.0	58.9	7.9	9.8

of health and are presented in Table 17, along with those based on the SHoS (Clark *et al.* (2004) for comparison. Note that data were not available below age 16 in the SHeS so the morbidity prevalence for age 0–15 was assumed to be the same as that for age 16–19. Similarly, prevalence rates at ages above 74 were assumed to be the same as those for age 70–74. The three definitions are:

(a) HE (SAH=1,2): 'good health' = responses '1 = very good' or '2 = good' to the SAH question.
(b) HE (SAH=1,2,3): 'good health' = responses '1 = very good', '2 = good' or '3 = fair' to the SAH question.
(c) HE (LLI): 'good health' = no limiting long-standing illness of any kind.

The major feature of these estimates, as noted before in respect of those based on the SHoS, is the very low HE based on LLI, and based on SAH in the SHeS if response 3 ('fair') is classed as bad health. This is similar to the problem that Bajekal *et al.* (2000) reported, in reconciling HE based on the GHS and on the HSE.

The estimates based on LLI in the SHeS are not quite as low as those based on LLI in the SHoS, but they are quite close. Therefore, in two separate surveys this measure has suggested that the Scottish population has extremely poor health.

9. Linkage of the Scottish Health Survey to Scottish Medical Records

9.1 *Linkage of Hospital and Survey Records*

Using the unique identifier allocated to everyone registered with the NHS in Scotland, it was possible for ISD to extract, from its records of hospital episodes in Scotland, a complete sequence of data for each person in the survey available for linkage (see above), going back to 1981. Each hospital episode consists of an admission and a discharge, and detailed information on the reason for admission (using ICD disease codes) and the treatment given. The linked database contains the 7,974 SHeS records, and details of

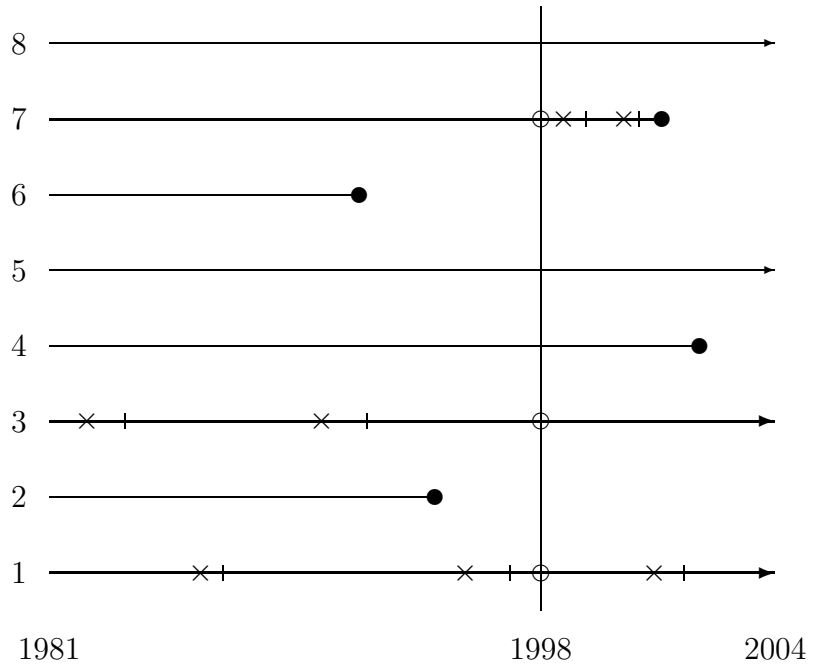

Figure 5: Graphical representation of the linked data set. Horizontal lines represent the life histories of 8 persons in 1981–2004. The vertical line represents the Scottish Health Survey; those included in the survey in 1998 are indicated by white circles in the survey year, while deaths are indicated by black circles. Persons 2 and 6 died before 1998 so could not be in the sample, while persons 4, 5 and 8 were (randomly) not sampled. In respect of persons sampled we have records of all hospital admissions (cross) and discharges (vertical line) as well as the responses to the survey. In respect of persons not sampled we have no data.

29,744 acute hospital admissions (SMR01), 807 psychiatric admissions (SMR04), 627 cancers (SMR06) and 416 deaths, a total of 39,568 records. 1,978 persons had no medical or death record during the entire period 1981 to March 2004, leaving 5,996 persons with at least one such record, averaging about 5 records each. It is important to note that there are no deaths before 1998 because being alive at the survey is a condition for linkage. The effect of this will be discussed later.

Figure 5 represents the linked data. We see that three persons were sampled in the SHeS out of eight life histories, two of which ended in death before the survey date so could not be included. One of the lives sampled had hospital treatment after the survey, another before the survey and the third both before and after the survey. The figure only represents the event of sampling and, conditional on that, the times of admission and discharge; it does not represent the rich ancillary data recorded in respect of these events.

The potential value of the linked data lies in the fact that it is currently the only longitudinal study of health data in Scotland that will be continually updated: now that the linkage to hospital records has been made, future episodes and deaths can be added

periodically[20]. Thus it offers insights as nearly as possible in real time into the changing health of the population. This is why we undertook the following preliminary investigation of the data in this study.

Figure 6 shows, for illustration, the distributions of times since the last serious (ICD codes) hospital event at the survey date, for those who had had episodes, depending on LI and LLI status. Persons reporting poorer health do tend to have had a more recent hospital episode, but this should be interpreted with caution since these are distributions conditional on having survived to the survey date.

9.2 *Using Hospital Episodes to Define Good and Bad Health*

Not all hospital admissions suggest that a serious or limiting illness is present. If the linked data are to contribute to the measurement of HE, serious admissions that are more likely to be associated with sensible definitions of 'bad health' must be distinguished from less serious admissions.

(a) The linked data include the ICD codes associated with the reason for admission, and this is an obvious (and universal) choice. We classified ICD codes depending on the extent to which diseases might be self-limiting[21].

(b) A second and potentially more useful approach was Healthcare Resource Group (HRG) codes assigned to SMR01 episodes. The codes depend on both severity of the disease and on the treatment, and are mapped onto a numeric scale representing severity. In the study we define a serious hospital episode as one with a HRG value of at least 1.1, to be consistent with the use of the HRG codes in a related project within ISD. Lacking similar information for psychiatric admissions, we assumed all such episodes to be serious. A drawback of the HRG codes is that they are only assigned to episodes from April 1997. Hence any use of earlier episodes must rely on the ICD codes.

The HRG codes are more discriminating than the ICD codes; more episodes are deemed serious under the latter. For example, all diseases of the circulatory system are deemed serious under the ICD coding, including heart disease, hypertensive disease, cerebrovascular disease and so on, not all equally serious in fact. The HRG code picks out diseases needing more intensive treatment; for example a heart transplant (HRG value 18.05) or cardiac arrest (1.20) would be serious under either definition, while an admission due to hypertensive disease has HRG value 0.68 or 0.80 depending on severity, so would only be serious under our ICD classification. Where possible we use the HRG codes, and when we cannot we use the ICD codes as a proxy. We can be reasonably sure that they measure the same qualities however: if e_i^{ICD} is the total number of serious episodes suffered

[20]When it becomes available, the Scottish Longitudinal Survey (SLS) will sample 5% of census records, linking the 1991 and 2001 censuses and hospital records. The methodology we discuss here should also be applicable to the SLS.

[21]The diseases regarded as non-limiting were ICD9 codes starting with 001–139 (infectious diseases) except 042–HIV, 210–239 (non-malignant neoplasms), 240–279 (endocrine, nutritional, metabolic and immunity disorders) except complications of diabetes, 630–677 (complications of pregnancy and childbirth), 740–999 (congenital anomalies, childhood conditions and ill-defined conditions), and the supplementary categories V101–V85 and E800–E999. The ICD codes changed in April 1996 and after that we used the equivalent ICD10 codes. We are not aware of a better categorisation but this would be useful future work.

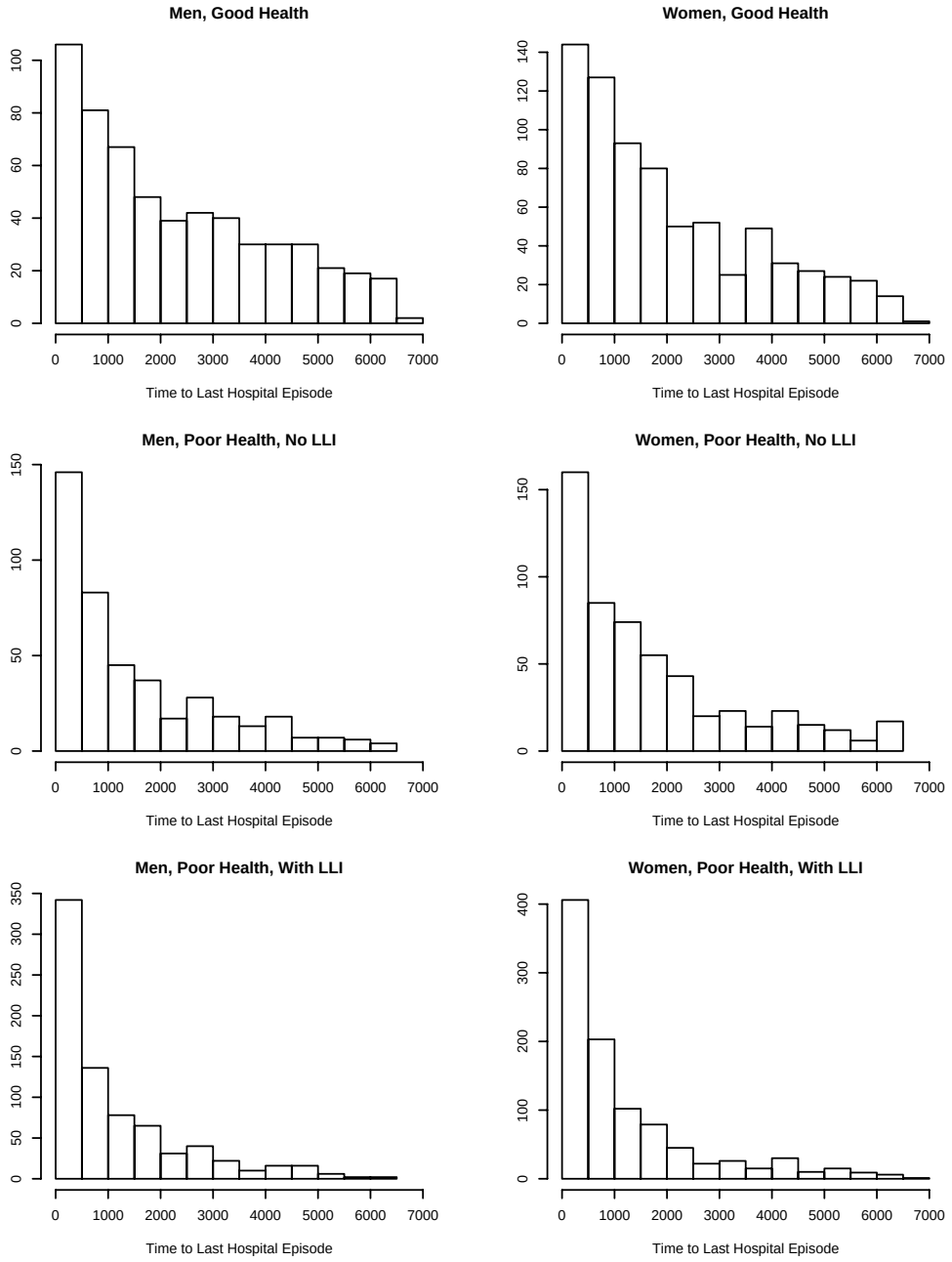

Figure 6: Distribution of time since last serious (ICD codes) hospital record at the survey date, conditional on having one, and depending on the presence or absence of long-standing and limiting long-standing illnesses.

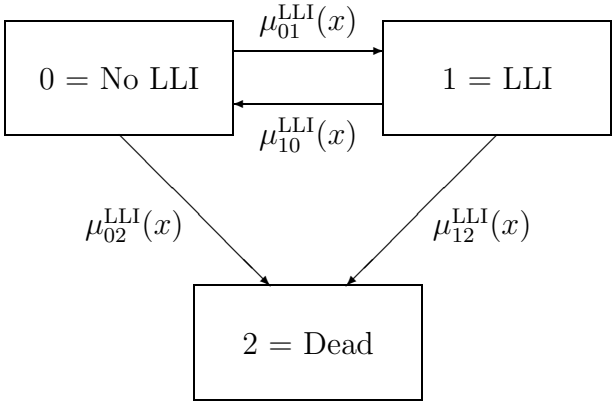

Figure 7: A model of limiting long-term illness (LLI).

post-survey by the ith person under the ICD coding, and t_i^{ICD} the accumulated time in hospital; and if e_i^{HRG} and t_i^{ICD} are the corresponding quantities under the HRG coding, we find that $\mathrm{Cov}[e^{\mathrm{ICD}}, e^{\mathrm{HRG}}] = 0.72$ and $\mathrm{Cov}[t^{\mathrm{ICD}}, t^{\mathrm{HRG}}] = 0.92$.

9.3 *Models Based on the Linked Data*

The first question to examine is what useful models may be suggested to account for the data generated by the survey members, given the linkage to their hospital records. By 'useful' we mean having a bearing on the estimation of HE. The multiple-state formulation seen before seems to offer some possibilities, the question being what criterion of good health to use. However, the linkage to the SHeS imposes a very particular structure on the data that has consequences for the estimation of HE. In the following example, we suppose that the relevant survey response is the presence or absence of a LLI, though this could be replaced by any other measure quantified by the SHeS.

A suitable model is specified in two parts: events that happen at random times, and additional information may be collected when one of these events occurs. For example, when a long-term illness begins we may record the illness or accident that caused it. Such ancillary data collected when events occur are often called 'marks'. The history of such a process, if we are able to observe it completely, consists of the times and types of all past transitions and the associated marks. There is a difference between knowing the current state of a process (for example, a person's current state of health but not their past medical history) which we denote $\mathcal{G}$, and knowing its past history as well, which we denote $\mathcal{F}$.

(a) Figure 7 indicates that the criterion of poor health is limiting long-term illness (LLI) and the intensities are denoted $\mu_{jk}^{\mathrm{LLI}}(x)$. We denote its current state at time t $\mathcal{G}_t^{\mathrm{LLI}}$ and its history at time t $\mathcal{F}_t^{\mathrm{LLI}}$.

(b) Figure 8 represents successive spells of hospital admission and discharge. The intensities are denoted $\mu_{jk}^{\mathrm{hosp}}(x)$ and the state and history at time t are denoted $\mathcal{G}_t^{\mathrm{hosp}}$ and $\mathcal{F}_t^{\mathrm{hosp}}$, the latter including knowledge of diagnosis and treatment.

We can now state precisely what the linked data provide. Let S be the survey date

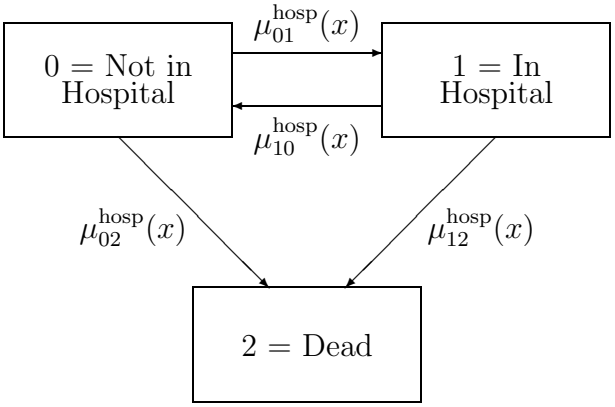

Figure 8: A model of hospital episodes. Associated with each hospital episode are two marks, *diag* = diagnosis and *treat* = treatment.

(ignoring for now that the survey was administered over 12 months) and let T be the latest time for which we have hospital records. The information we have is $\mathcal{G}_S^{\text{LLI}}$ and $\mathcal{F}_T^{\text{hosp}}$. This is less than we would like to have: in keeping with the attempt to define HE by way of a model of health states, we would like to observe $\mathcal{F}_T^{\text{LLI}}$ and $\mathcal{F}_T^{\text{hosp}}$ but we cannot. Further, we must take care to allow for the sampling scheme when necessary. The subjects were selected for the survey randomly (up to stratification) but conditional on being alive to be surveyed. The random sampling means it is reasonable to assume that the all the different life histories are mutually independent, but the need to be alive in 1998 to be surveyed means that the analysis of hospital episodes before 1998 is conditional on that outcome. This point is crucial: the sampling was done randomly in 1998 so the hospital records after that time constitute a *prospective* study, whereas the hospital records before that time constitute a *retrospective* study.

It is reasonable to assume that the two processes above (and others relating to SAH, LI or ADLs) are dependent, so that if any of SAH, LI, LLI and ADL impairment might often be associated with the need for hospital treatment, the history of hospital episodes is drawn in too. Such dependence means that in the absence of all the information we might desire, each part of the model may provide indirect information about the others. The question is: can this be exploited in any way in estimating HE?

10. Features of the Linked Data

Apart from exploring its general features, we may ask three reasonably sharp questions of the linked data. First, does hospitalisation offer a useable definition of 'good' and 'bad' health, therefore a new definition of HE? Second, is the past history at the survey date predictive of the survey responses used in the conventional definition of HE? And third, are those same responses predictive of future health and mortality?

In this section, 'onset' means admission to hospital, and the start of a spell in state 1 of Figure 8. Parameterising the model means estimating the transition intensities $\mu_{jk}^{\text{hosp}}(x)$.

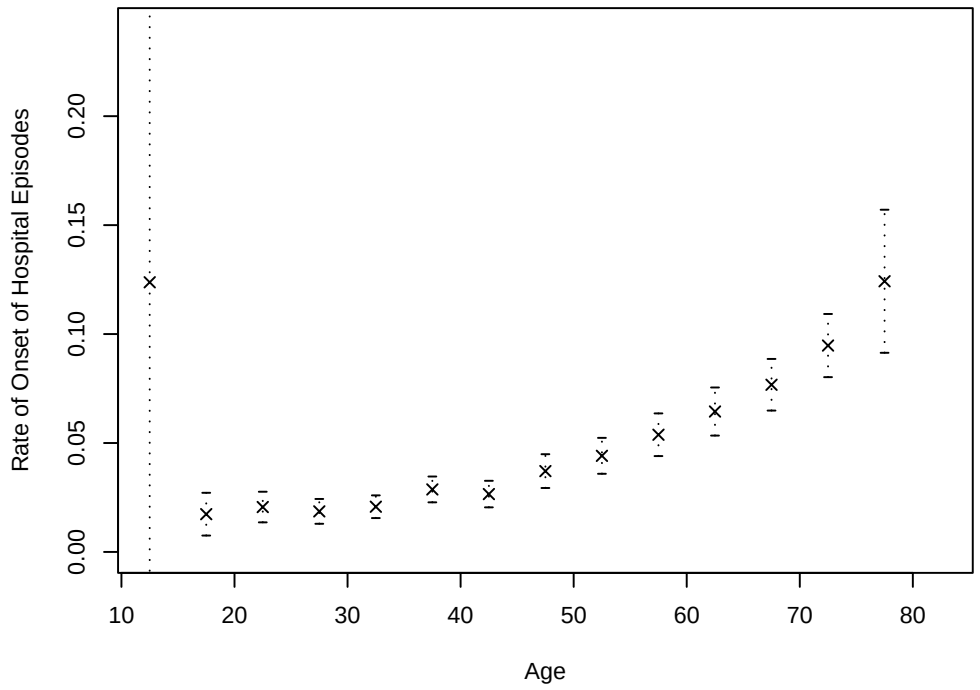

Figure 9: Annual rates of onset of first serious hospital episode in 1997–2004, for females. A serious episode is defined as one with an HRG score of 1.1 or more.

Strictly, only the post-survey data should be used in this task. The reason is that subjects had to be alive at the survey date to be included, so while we certainly could calculate occurrence-exposure rates using pre-survey data, they would not be estimating the parameters we want[22]. The use of pre-survey data therefore ought to be limited to possible explanations of the survey responses. However, we have calculated onset rates from the first time that the HRG codes were available, namely April 1997, therefore do include a small pre-survey period. The effect is small.

Figures 9 and 10 show rates of onset ($\mu_{01}^{\text{hosp}}(x)$ in Figure 8) of *first* serious hospital episodes for females and males, for age groups 10–14, 15–20, ..., 75–79. Those in the lowest age group are based on very small numbers and we disregard them. Here 'serious' is defined as an episode with a HRG score of 1.1 or over. The use of the first episode since the survey has the effect of ignoring, for the moment, the possibility of recovery and further episodes; the rates $\mu_{01}^{\text{hosp}}(x)$ would be higher. Even so it is evident at once that onset rates, so defined, are so high that a very high proportion of the population would fall under this definition of disability by late middle age. For example, ignoring deaths

[22]To express this more precisely, it helps to let the intensities depend on calendar time as well as age, thus $\mu_{jk}^{\text{hosp}}(x,t)$. Then an occurrence-exposure rate of onset based on pre-survey data would not be an estimate of $\mu_{01}^{\text{hosp}}(x,t)$ but of:

$$\mu_{01}^{\text{hosp}}(x,t) \times \frac{\text{P[Surviving to survey date} \mid \text{Onset has just occurred]}}{\text{P[Surviving to survey date]}}.$$

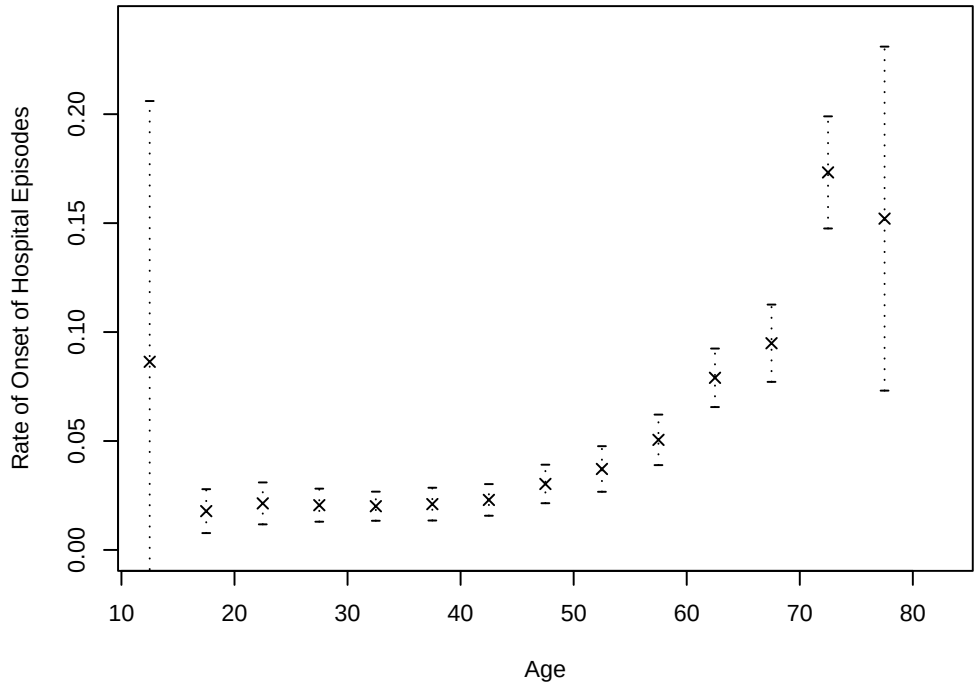

Figure 10: Annual rates of onset of first serious hospital episode in 1997–2004, for males. A serious episode is defined as one with an HRG score of 1.1 or more.

while healthy, about 40% of women would be so disabled by age 35, 70% by age 55 and 95% by age 75. This means that hospitalisation will not lead to a satisfactory definition of the HE unless recoveries (discharges) are also taken into account.

However, the average length of a serious hospital episode (HRG ≥ 1.1) was only 8.36 days, and each person surveyed suffered an average of 0.56 such episodes up to 2004. So although the probability of a serious hospital event is very high, the time spent in hospital is likely to be short. The combined effect is that if 'bad health' is defined as time spent in hospital, HE is practically the same as total LE. We did estimate HE on this basis by Sullivan's method, and it was uniformly greater than 99% of LE.

We conclude that any measure of HE in which hospital admissions play a direct rôle as 'onset' of bad health must associate, with each admission, a time spent in bad health other than the time until discharge. The linked data do not include any such interval data. It is possible that widening the linkage to non-hospital medical records, such as those of general practices, would give more insight into recoveries from bad to good health, but this is speculative. It is perhaps inevitable that the onset of bad health should be relatively easy to observe, because that is when people ask for help; it is much harder to observe when people stop needing help. The linked data succeed in doing so because they measure the delivery of acute services in managed premises, but by the same token they do not capture the broader notions of good health that underlie most conceptions of HE.

We have no grounds for associating an arbitrarily chosen period of bad health (for example, a year) with each serious hospital episode[23]. The most we might learn is what

[23]The idea of linking together reasonably contiguous periods of bad health is appealing at first, but

average length of hospital stay would equate HE, so measured, with HE based on SHeS, SHoS or GHS survey data, which seems a poor return from such a data set. Instead we propose other lines of investigation.

11. Linking Pre-Survey and Post-Survey Event Histories

11.1 *Pre-Survey and Post-Survey Periods*

The survey divides the period 1981–2004 into pre-survey and post-survey periods. A natural question is: what do the survey repsonses and/or pre-survey life histories (hospital episodes only, no deaths) tell us about the life histories post-survey (hospital admissions and deaths)? It might be thought that any arbitrary date might be chosen to define 'pre' and 'post', especially one that would allocate more years to 'post'. This is not so, because the survey also divides 1981–2004 into periods of retrospective and prospective observations, that we may not treat alike. The opportunity presented by the linked data, to follow up the respondents to a health survey for a lengthy period, is unique in Scotland and very unusual anywhere.

11.2 *Post-Survey Mortality*

We have about six years of follow-up since the survey, on a properly prospective basis, so we can undertake standard survival analysis, conditioning on the survey responses. We can target two events; survival until death, or survival until the first serious hospital episode, since both are in the linked data.

Figure 11 shows Kaplan-Meier estimates[24] (and 95% confidence intervals) of the probabilities of surviving alive up to 2,142 days (5.9 years) since the survey date, depending on SAH responses, for age groups 45–54, 55–64 and 65–74, for males (left) and females (right). Note that the vertical scales are not the same for different age groups, which form the rows. Numbers of deaths at ages 20–44 did not support similar estimates.

As an example, consider males age 65–74 (bottom left plot). The three lines near the top are the estimated survival probability (middle line) and its upper and lower 95% confidence intervals, for men in good SAH, who gave responses 1 or 2 to the SAH question. The steeply falling lines lower down are the corresponding quantities for men in poor SAH. Each plot in the figure includes a p-value, the result of a log-rank test for lack of difference between two sets of censored data. In many cases the p-values confirm what is obvious to the eye.

There is a striking reversal between the relative prospects of men and women between ages 55–54 and 65–74. At the younger ages unhealthy women have worse mortality than

then we must ask, when does a period of bad health end, if another hospital event does not come along to keep it going? Thus we have to introduce an arbitrary limit to periods of bad health to make up for the absence of any signal that it has ended. This is equivalent to choosing an arbitrary period of bad health.

[24]The Kaplan-Meier estimate is similar to the empirical survival function $(1 - \hat{F}_T(t))$ where $\hat{F}_T(t)$ is the empirical distribution function of T, the random time until death, but it allows for censoring (the fact that not all death times are observed). Given that 331 SHeS subjects who might have migrated were excluded from the linked data, we assume that observation of time-until-death is censored only by the linkage stopping in 2004. If other unobserved exits are present in the data, these estimates will be overstated.

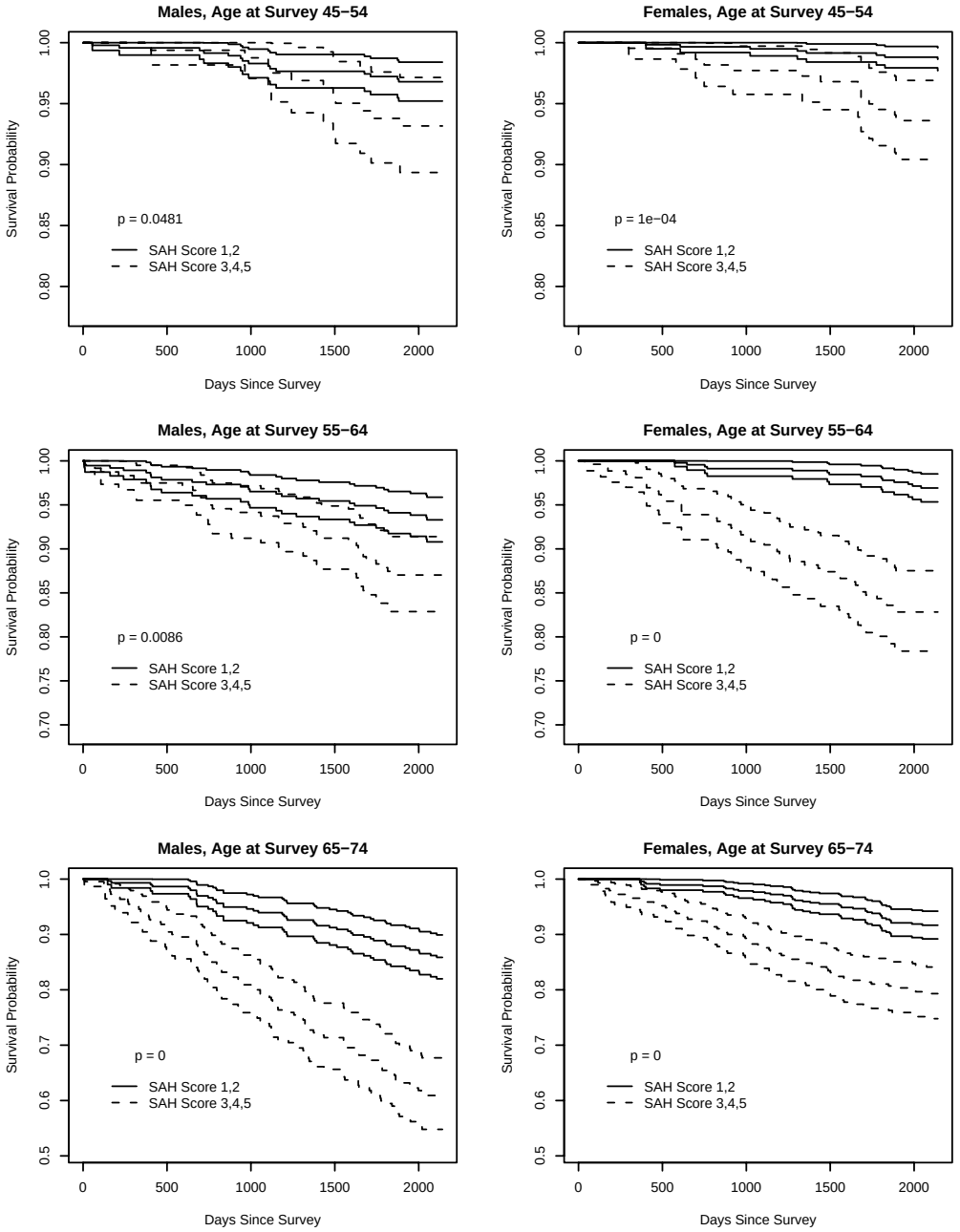

Figure 11: Kaplan-Meier estimates of survival probabilities post-survey, (with 95% confidence intervals) depending on self-assessed health, responses of 3, 4 and 5 classified as 'poor health'. Note that the vertical scales are not the same for all age groups (rows).

men, at the older ages it is the other way round, very much so, even though the normal relationship always holds for men and women in good health.

It is conventional and often useful to include confidence intervals in graphs of this kind, but in our case we usually have quite widely separated estimates with very small p-values (as for males age 65–74) or else closer estimates with larger p-values but overlapping confidence intervals (as for males age 45–54). Therefore, showing confidence intervals often either restates the obvious or leans rather heavily on the p-values to interpret a cluttered picture.

An alternative presentation of the same data is shown in Figure 12. The Kaplan-Meier estimates are shown without their confidence intervals, except at the longest duration (right hand side) where 95% confidence intervals are indicated by crosses (higher estimate) or triangles (lower estimate). The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of mortality of the upper Kaplan-Meier estimate[25]. This makes it easy to assess the impact of a factor such as different levels of SAH in terms of multiples of the better mortality. For example in Figure 12, men age 55–64 with poor SAH suffer very close to double the mortality rates of men of the same age with good SAH. The p-values are still shown. On balance we prefer this way of illustrating the data.

Figure 13 shows the corresponding results if response 3 to the SAH question ('fair') is included in good rather than bad health. Figures 11 and 13 are hard to interpret at ages 45–54, but they show that the SAH question is quite strongly predictive of short- and medium-term mortality at ages over 55. Recall (Table 17) the very great rise in HE based on SAH if response 3 ('fair') was classified as 'good health'. While mortality given 'poor health' clearly is worse in Figure 13, it is not greatly so and the 'poor health' group is quite small.

We commented above on the striking reversal of mens' and womens' relative positions shown by Figure 11. Figure 12 puts this into some perspective. At ages 55–64, men with poor SAH have mortality rates about twice those of men with good SAH, after about two years. Women with poor SAH, however, have mortality rates far in excess of 5 times those of women with good SAH. At ages 55–64, men and women are not so different. Comparison with Figure 13 suggests that allocating response 3 ('fair') to one or other health status is very influential for women age 55–64, or that women in this age group giving responses 1 or 2 had very low mortality.

Figure 14 (which corresponds to the definition of HE used most often in the UK) shows the LLI-based definition to have predictive qualities similar to the SAH-based definitions, but less discrimination, which is consistent with the numbers of responses in Tables 14 and 15.

Figures 15 and 16 show, for males and females respectively, survival probabilities given the prior occurrence of a serious hospital episode (ICD coding) within 500 days, 1,500 days or any time between 1981 and the survey. Only age groups 55–64 and 65–74 are shown, and note that in these graphs they form the columns. Of 416 deaths in the

[25] Actuaries will be familiar with the common practice in insurance underwriting of rating risks as $+X\%$ of the mortality rates of some standard life table. This is very similar, except that instead of holding to a single standard rate (force) of mortality throughout, we assess the higher risk with respect to the lower risk in each particular case.

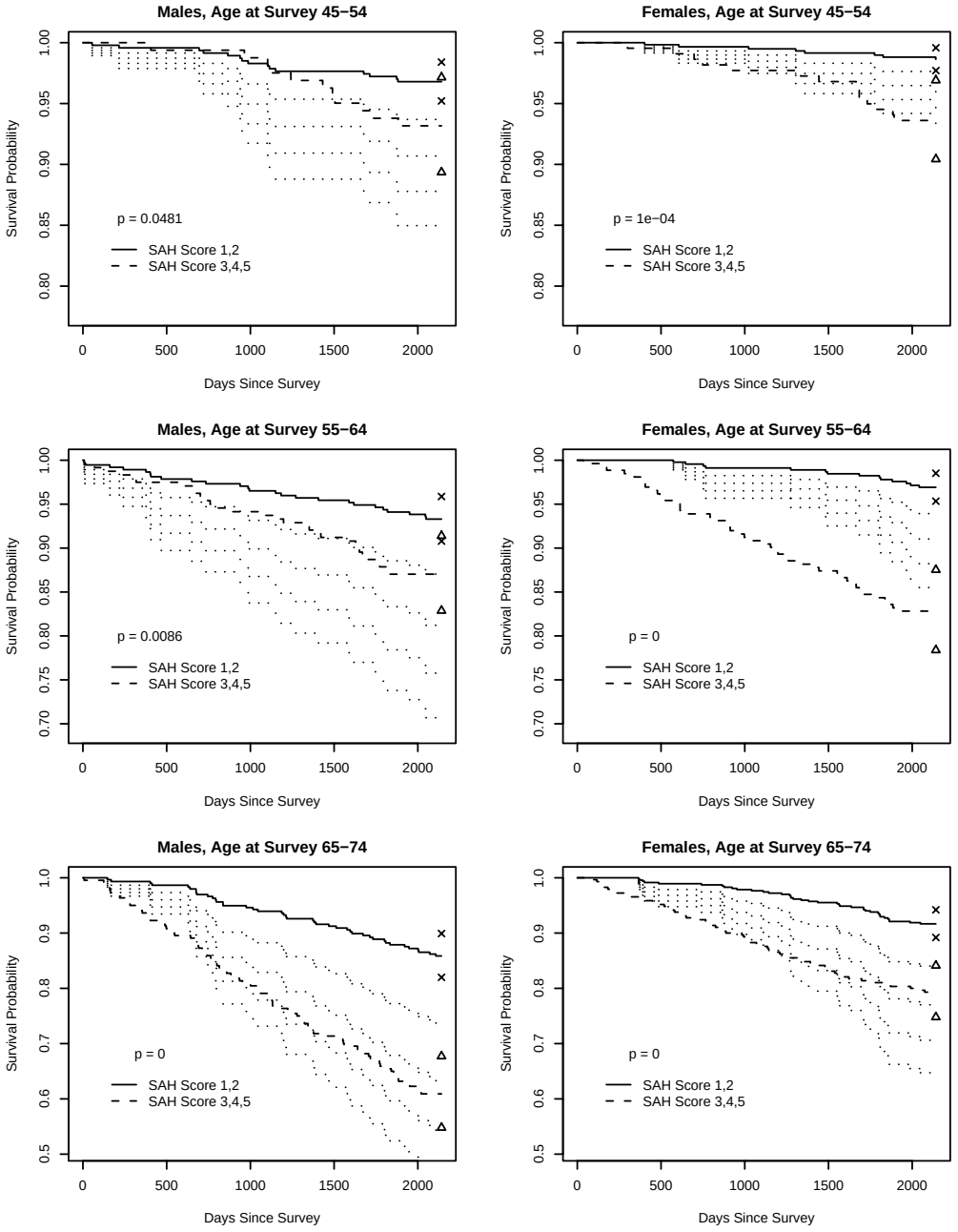

Figure 12: Kaplan-Meier estimates of survival probabilities post-survey, depending on self-assessed health, responses of 3, 4 and 5 classified as unhealthy. The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of mortality of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for all age groups (rows).

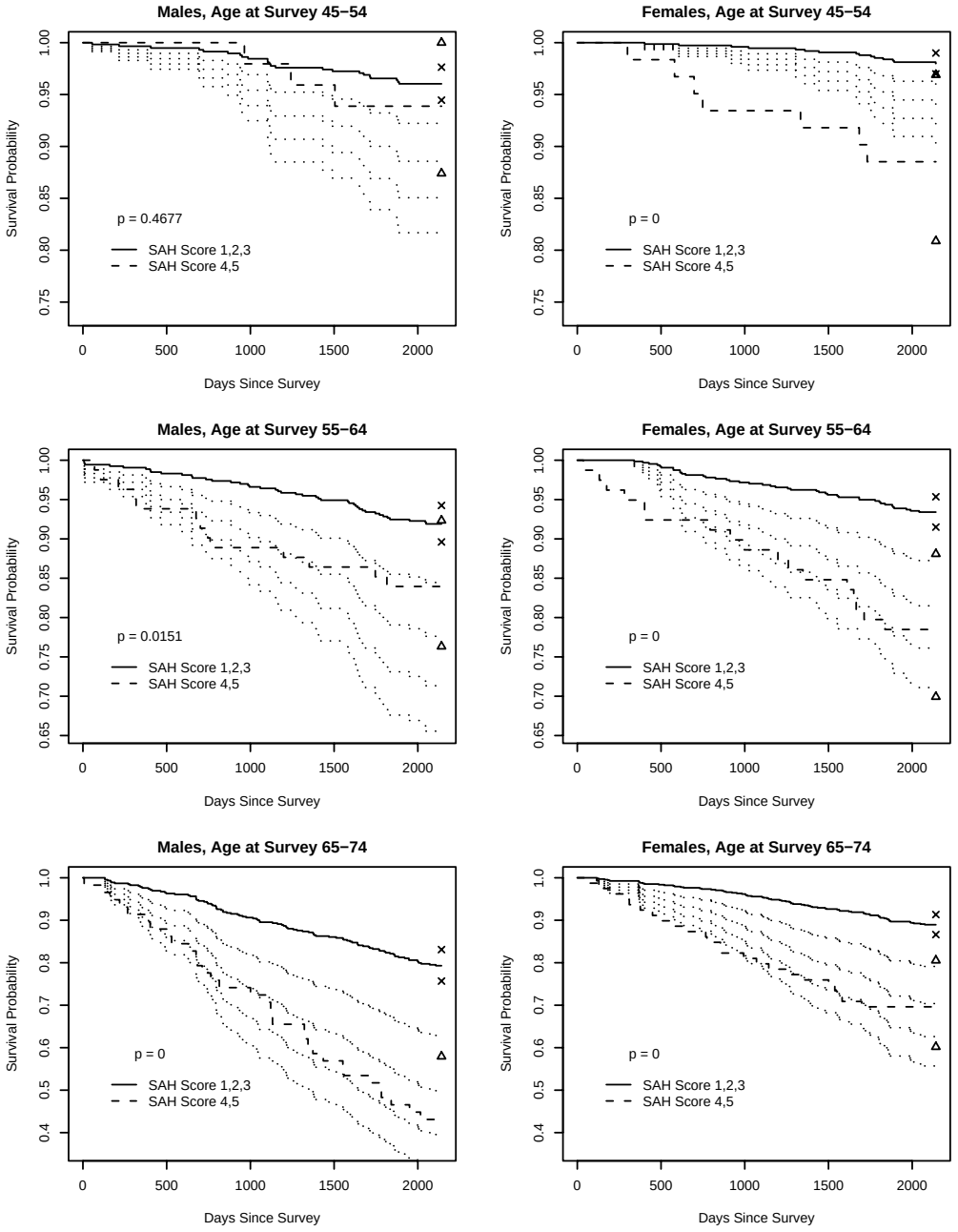

Figure 13: Kaplan-Meier estimates of survival probabilities post-survey, depending on self-assessed health, responses of 4 and 5 classified as unhealthy. The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of mortality of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for all age groups (rows).

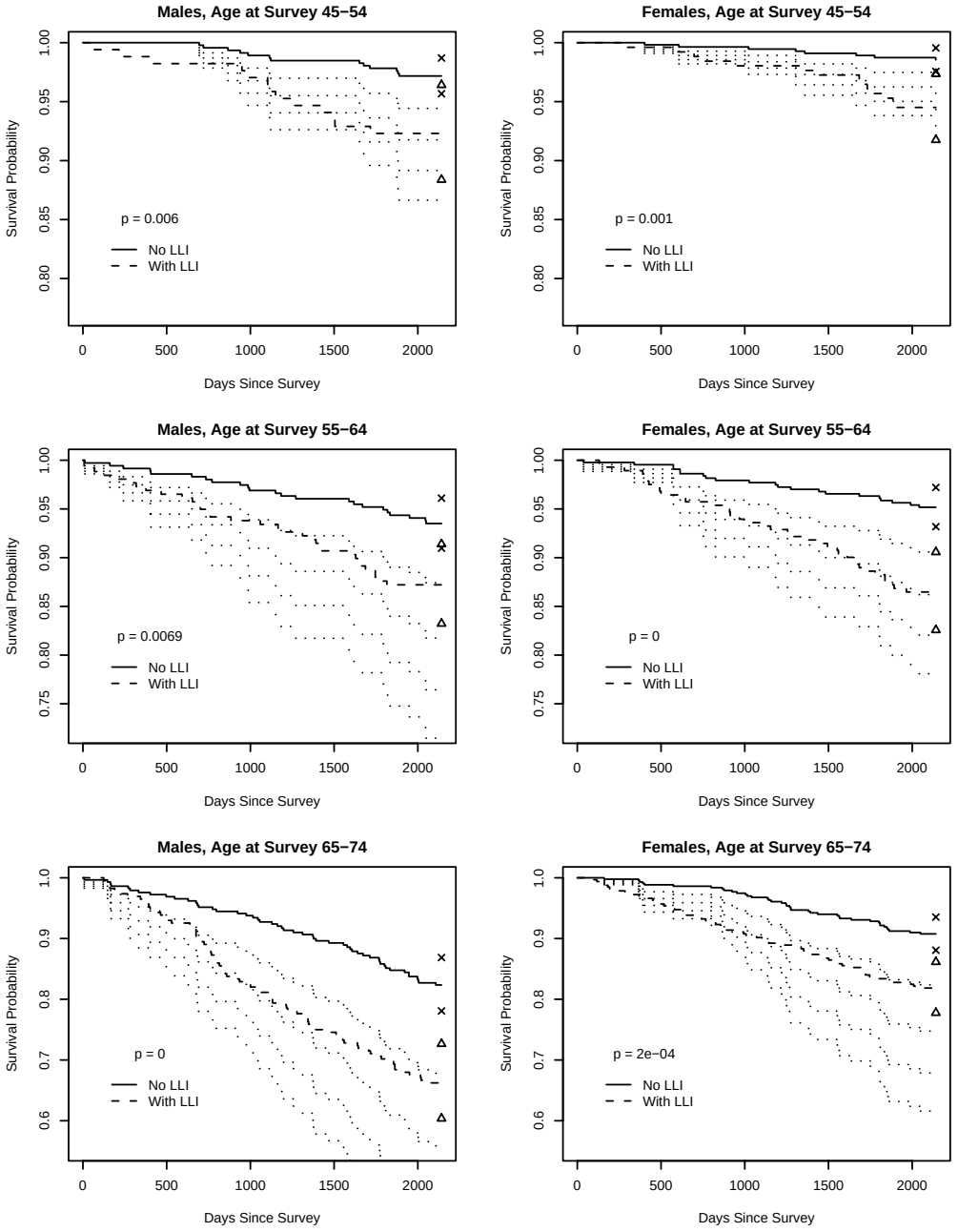

Figure 14: Kaplan-Meier estimates of survival probabilities post-survey, depending on the presence or absence of a limiting long-term illness. The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of mortality of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for all age groups (rows).

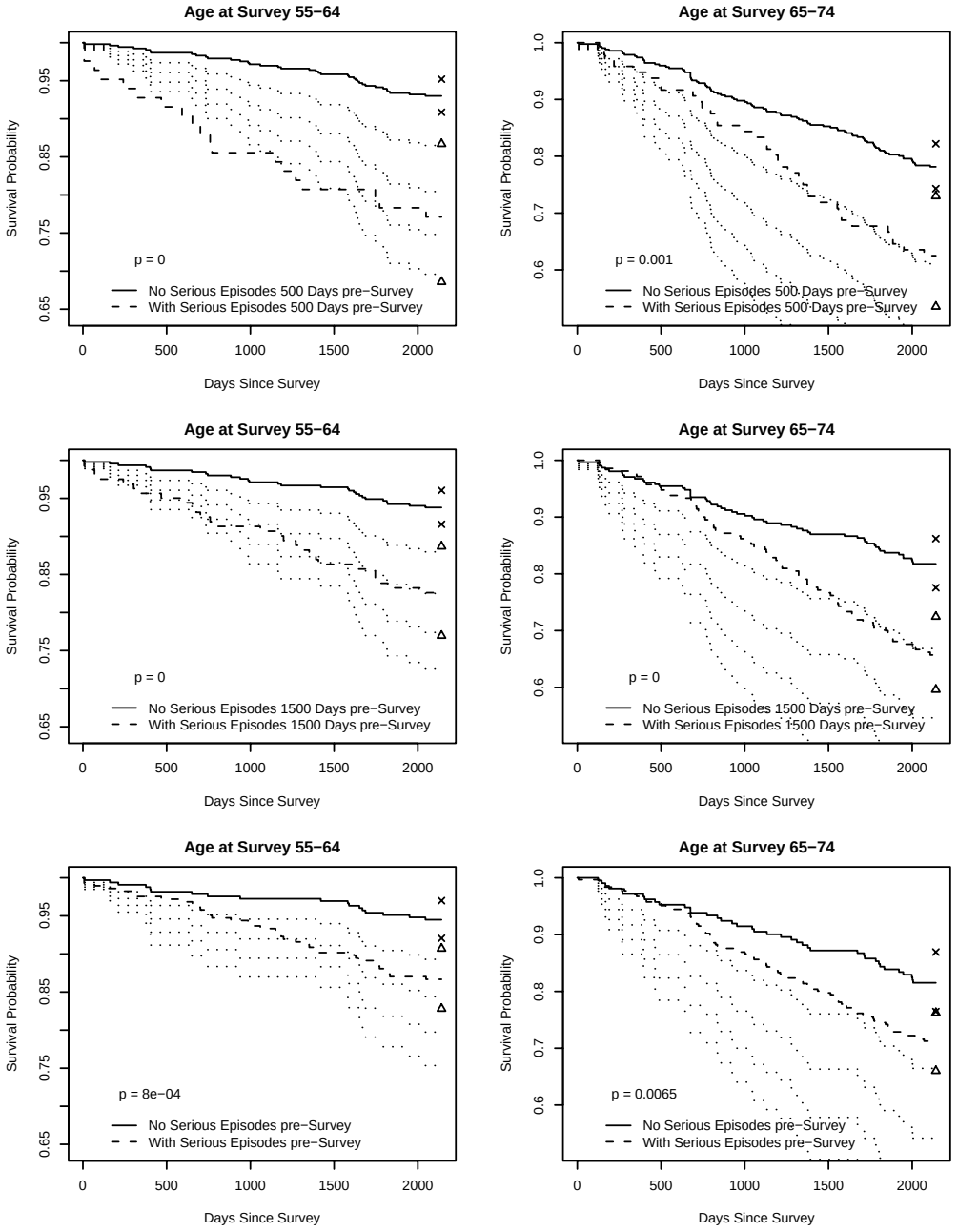

Figure 15: Kaplan-Meier estimates of survival probabilities post-survey, depending on the duration at the survey date since the last serious hospital episode (for males, ages 55–74). The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of mortality of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for both age groups (columns).

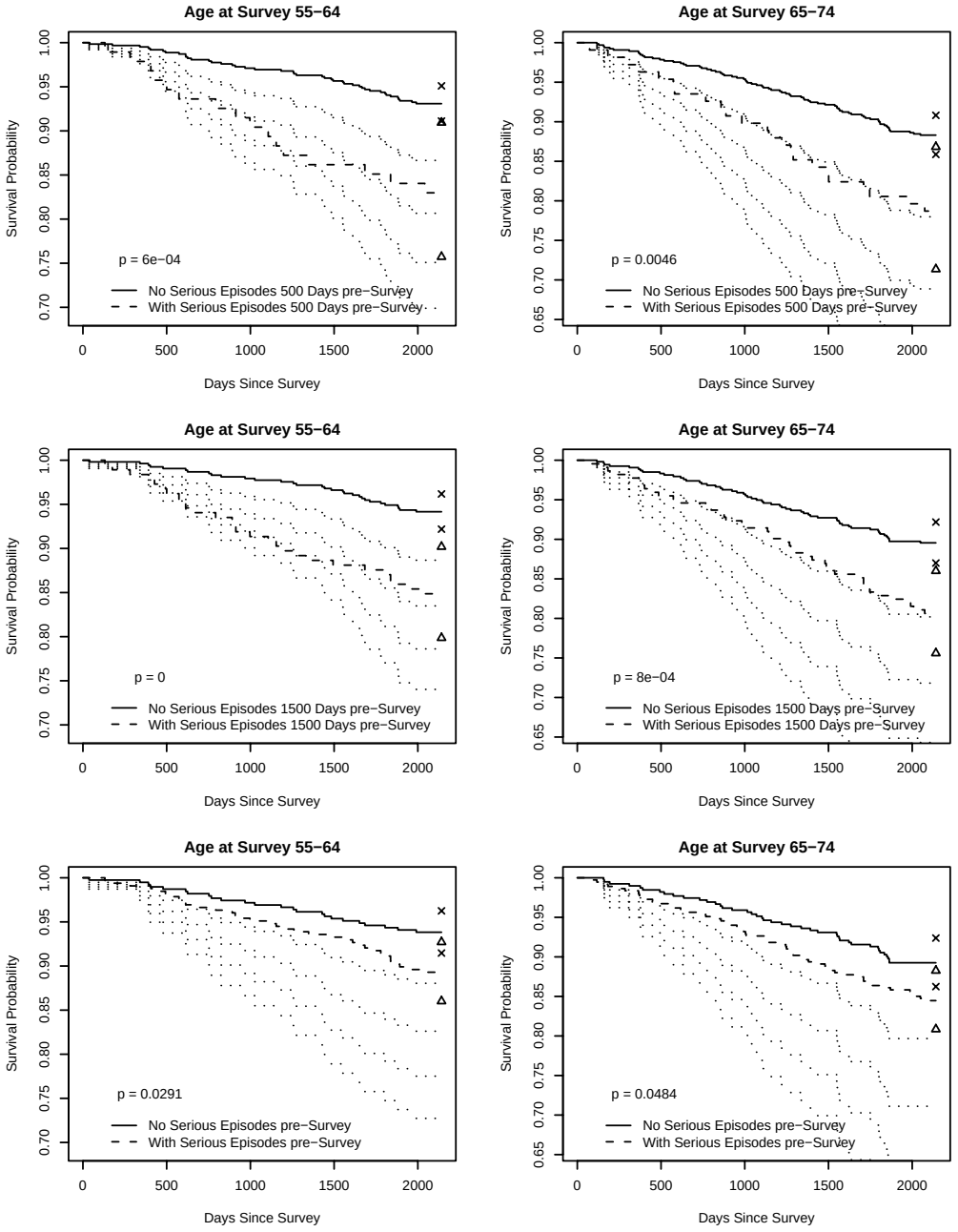

Figure 16: Kaplan-Meier estimates of survival probabilities post-survey, depending on the duration at the survey date since the last serious hospital episode (for females, ages 55–74). The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of mortality of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for both age groups (columns).

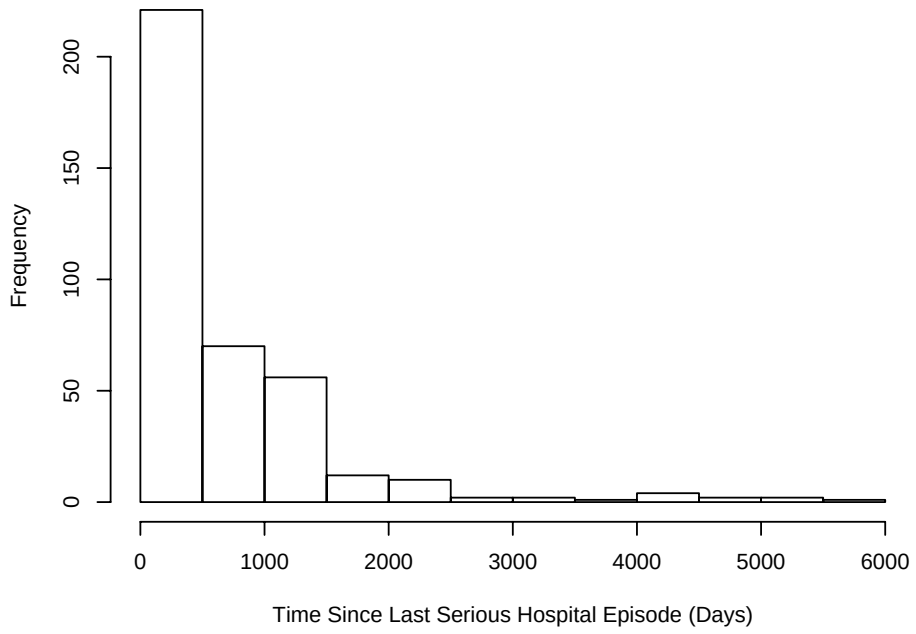

Figure 17: Distribution of time (days) between last serious hospital episode and death, for the 383 (out of 416) deaths that were preceded by such an episode.

data, 83 occurred with no serious episode (HRG) post-survey, of which 33 had no serious episode (ICD) pre-survey either. Figure 17 shows the distribution, at death, of the time since the previous serious episode, where there was one.

It is as expected that a prior episode increases risk, what is of interest is the contrast with self-reported health. Comparing the two sets of figures, we see that the sex differences noted above are much less strong, though not completely absent. This could be caused by differences in the way that men and women self-report their health, which would suggest that hospital episodes do give a more objective measure.

Although the existence of a hospital episode is predictive of future mortality, the extent to which the duration since it occurred is predictive varies greatly with age. At ages 55–64 duration is strongly predictive, for men and women, but at ages 65–74 it makes rather little difference.

Actuaries are familiar with select life tables, which reflect the fact that someone who has just been accepted for life insurance will have given some evidence of good health, and the mortality experience of such people will for some time be better than average. In the UK it has been common to assume that this effect will wear off after 2 or 5 years, although in the USA it is common to assume much longer 'select periods'. What Figures 15 and 16 show is how persistent is the selection effect, given that the pre-survey period extends over 17 years.

Six years is a relatively short follow-up period; it suffices to extract patterns for older age groups but not for younger age groups, and this particular sample has yet to age into the oldest-old age groups. Therefore, survival analysis may yield more and more useful information as time passes and the more records are linked to the data.

11.3 *Post-Survey Morbidity*

The other 'survival' event that is accessible through the linked data is the time until first suffering a post-survey serious hospital episode. Except that prior death is now a censoring event rather than the event of interest, we can estimate 'survival' probabilities just as before. Figures 18 to 22 show the results, for the two definitions of HE based on SAH, that based on LLI, and the duration at survey since a previous serious episode, males and females, respectively. These correspond to Figures 12 to 16 above. Note that in Figures 21 and 22, serious events pre-survey are defined by ICD codes, while the event being studied — the first serious event post-survey — is defined by our preferred HRG codes.

The most obvious feature is that all the measures of health at the survey provide much stronger discrimination of future morbidity than of future mortality, especially at ages 45–54, where mortality rates are low anyway. The possible exception is at older ages for the SAH (responses 4 and 5 only) measure.

One striking feature in Figures 18 to 20 is the extent to which men and women are similar at ages 45–64, but at ages 65–74 the implications of poor self-reported health (including LLI and SAH) reduce for women but increase for men; that is, the morbidity experiences of women in poor and good self-reported health close up, while those of men diverge. This sex difference is not quite so apparent when the baseline measure of health is time since the last pre-survey serious episode.

As with mortality, the duration since a previous serious hospital episode matters more at ages 55–64 than at ages 65–74.

Comparing survival to first serious episode with survival until death, the probabilities of the former, for those in the adverse risk groups, have a curious feature of flattening out slightly at about 1,000 days after the survey, especially for men with a recent serious episode at the time of the survey, and for poor SAH (responses 4 and 5 only). A possible reason is a selection effect in the period following a serious episode.

11.4 *Implications for Health Expectancy Measurement in Scotland*

A clear and troubling feature of the Scottish HE estimates since Clark *et al.* (2004) published them has been the exceptionally low estimates based on LLI. Estimates based on SAH are not so extreme, except under the SHeS, if if response 3 ('fair') to the SAH question is counted as unhealthy, And, as Tables 14 and 15 show, if this is done the numbers reporting poor SAH and an LLI are very similar. The questions are: (a) are these measures consistent? and (b) do they genuinely pick out a group of people with poor health outcomes? The analyses of this section may help to answer these questions.

(a) It is obvious that if the different questions were answered consistently by the same people, the mortality and morbidity described in Section 11 would not depend on which question had been asked. Table 18 shows how many persons who reported a LLI also reported bad health under the SAH question. There was substantial overlap if response 3 ('fair') was counted as bad health, and only a small overlap if it was not. Therefore the similarity between Figures 12 and 14, and even more so between Figures 18 and 20, suggests that responses 3, 4 and 5 to the SAH question measure very much the same as reporting a LLI. This supports the conclusion reached by Bajekal *et al.* (2002), see the end of Section 7.

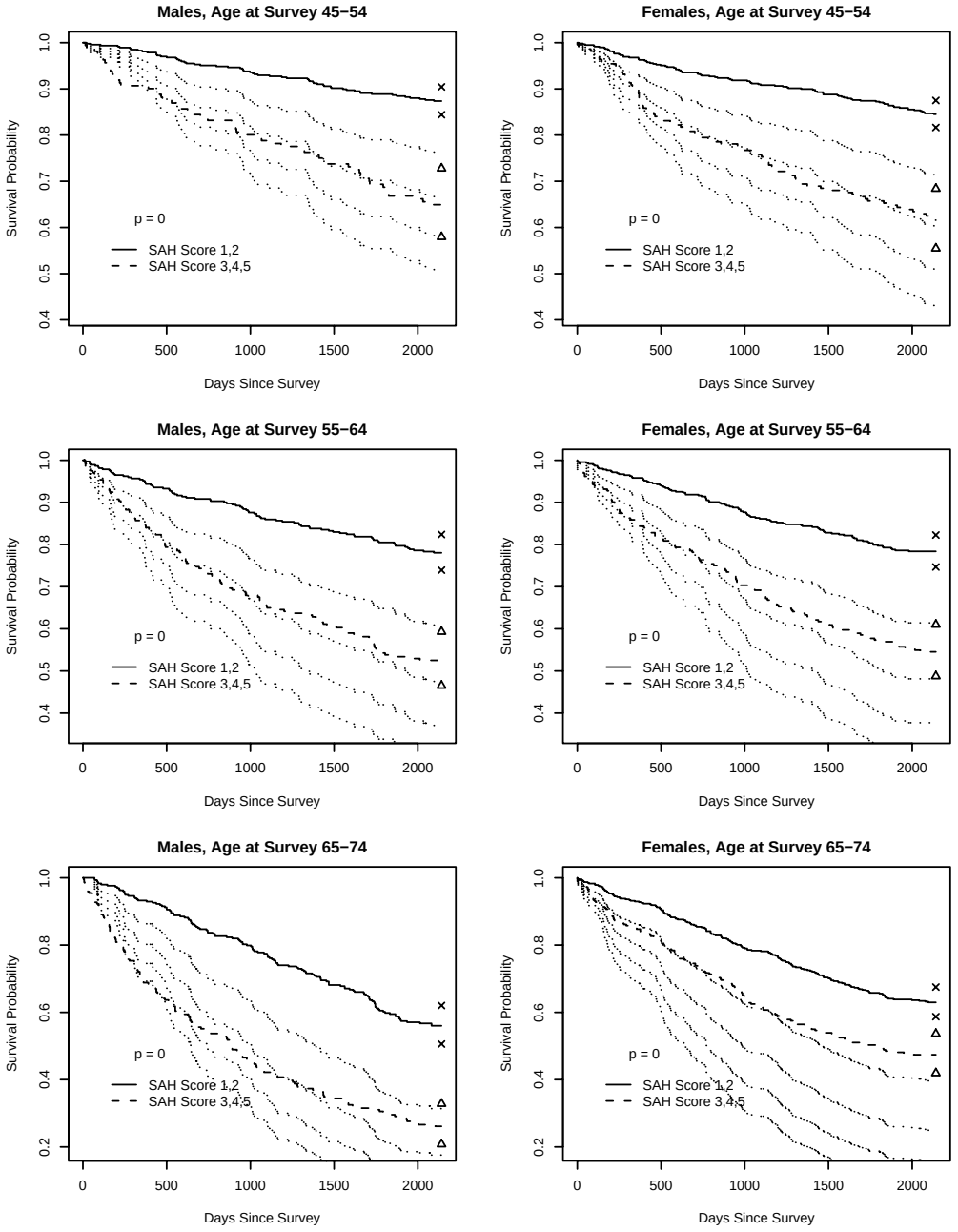

Figure 18: Kaplan-Meier estimates of the probability of surviving free of a serious hospital episode (HRG codes), depending on self-assessed health, responses of 3, 4 and 5 classified as unhealthy. The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of onset of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for all age groups (rows).

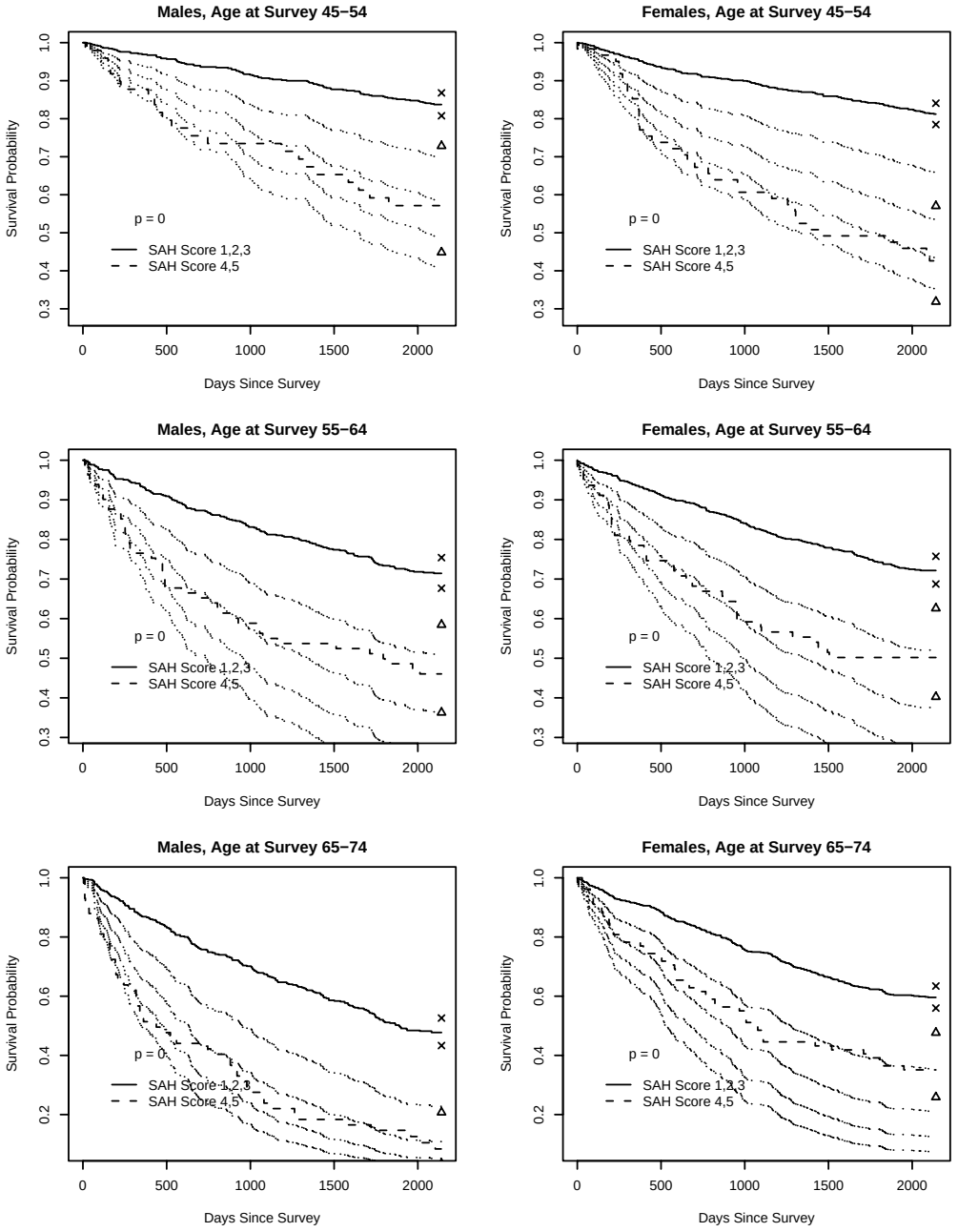

Figure 19: Kaplan-Meier estimates of the probability of surviving free of a serious hospital episode (HRG codes), depending on self-assessed health, responses of 4 and 5 classified as unhealthy. The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of onset of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for all age groups (rows).

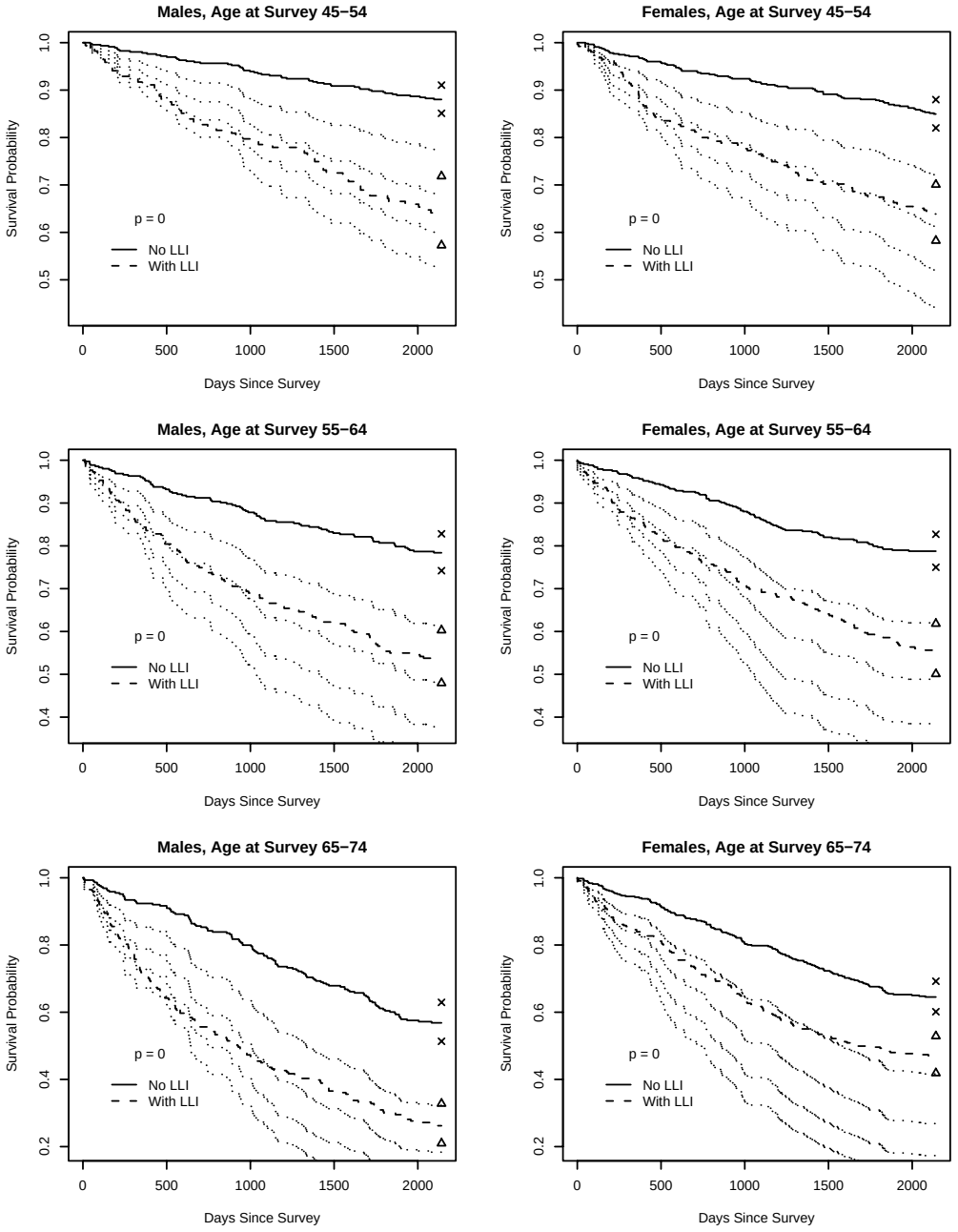

Figure 20: Kaplan-Meier estimates of the probability of surviving free of a serious hospital episode (HRG codes), depending on the presence or absence of a limiting long-term illness. The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of onset of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for all age groups (rows).

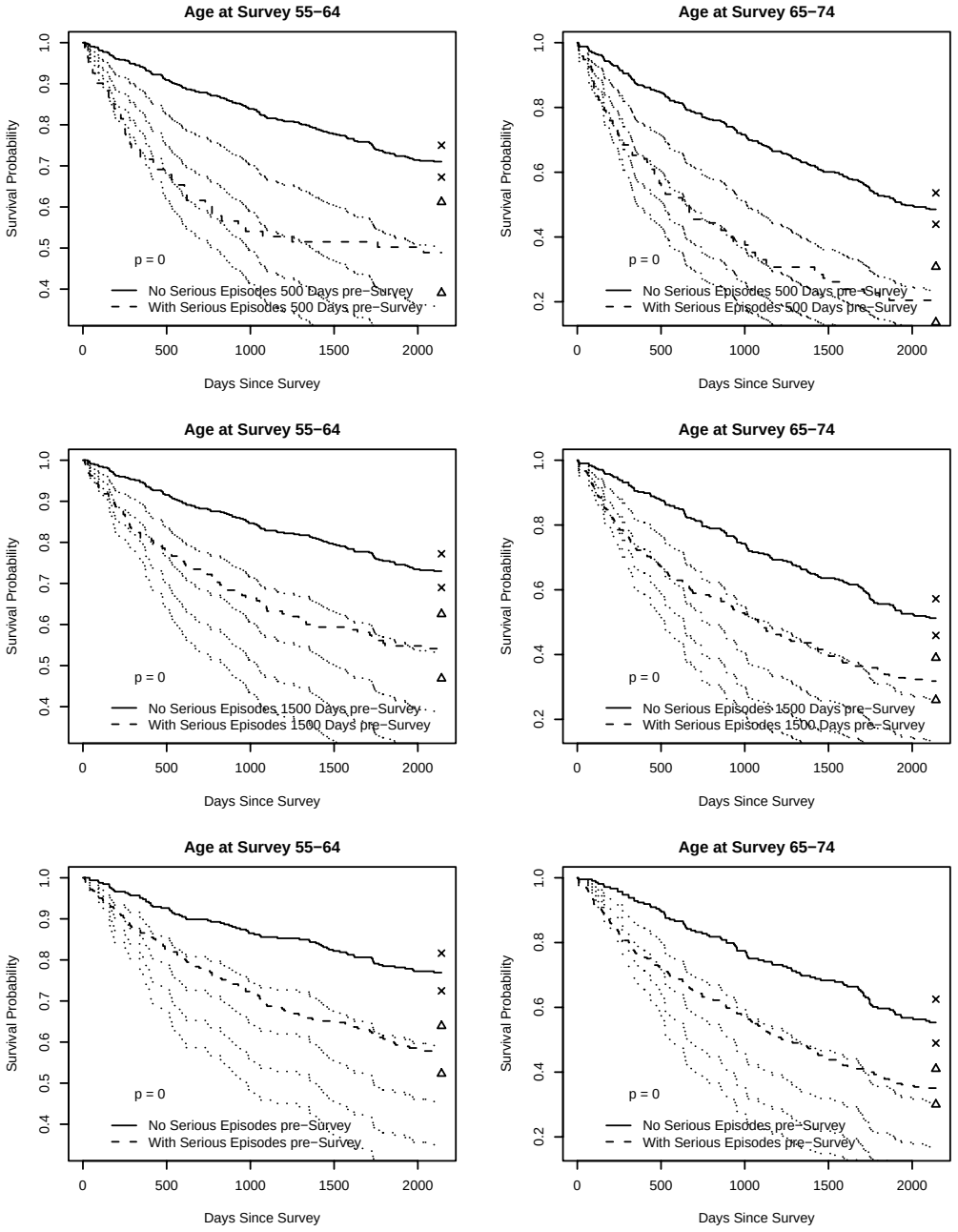

Figure 21: Kaplan-Meier estimates of the probability of surviving free of a serious hospital episode (HRG codes), depending on the duration at the survey date since the last serious hospital episode (for males, ages 55–74). The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of onset of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for both age groups (columns).

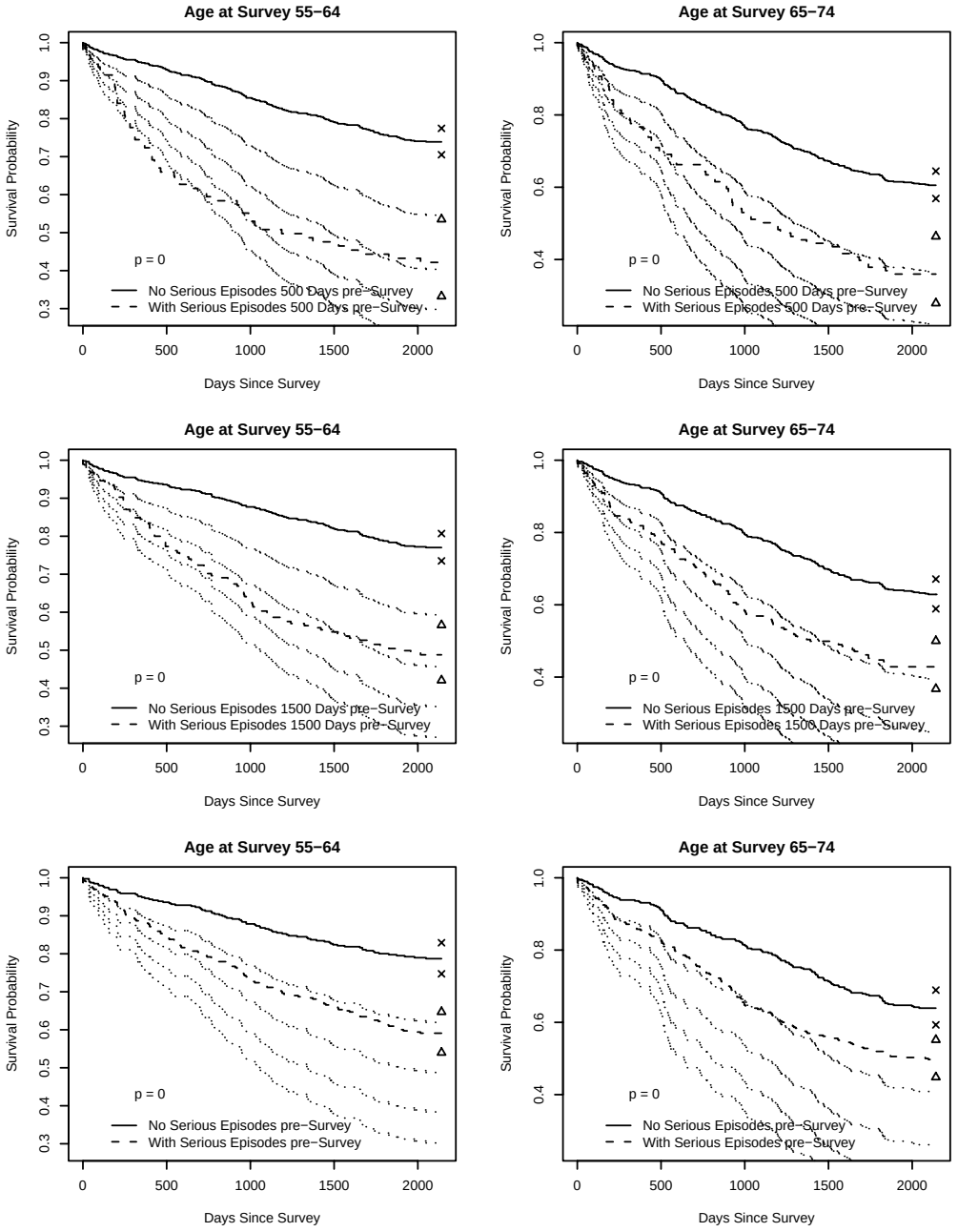

Figure 22: Kaplan-Meier estimates of the probability of surviving free of a serious hospital episode (HRG codes), depending on the duration at the survey date since the last serious hospital episode (for females, ages 55–74). The dotted lines show the survival probabilities corresponding to 2, 3, 4 and 5 times the force of onset of the upper Kaplan-Meier estimate. 95% confidence intervals at the longest duration are indicated by crosses (higher estimate) or triangles (lower estimate). Note that the vertical scales are not the same for both age groups (columns).

Table 18: Responses to the self-assessed health question in the 1998 Scottish Health Survey, by persons who reported a limiting long-standing illness.

	LLI		LLI and SAH=3,4,5		LLI and SAH=4,5	
Age Group	Males	Females	Males	Females	Males	Females
16-19	8	16	6	8	0	0
20-24	20	33	11	17	3	3
25-29	37	48	17	27	5	8
30-34	65	92	38	42	10	17
35-39	54	91	22	57	8	16
40-44	73	85	41	52	20	20
45-49	79	113	48	80	18	28
50-54	90	142	63	90	28	33
55-59	124	141	98	101	39	47
60-64	134	140	101	97	41	28
65-69	118	162	83	113	24	39
70-74	110	163	85	110	29	35
Total	912	1,226	613	794	225	274

(b) Our survival analyses show that the health questions almost universally used in surveys aimed at estimating HE are strong predictors of future mortality and morbidity. This is of course the assumption underlying their use, but it is unusual to be able to measure it, because most health surveys have no follow-up.

While it is difficult to form a conventional measure of HE from hospital records alone, we have shown that the risk of future hospital episodes, therefore use of health services, is quite strongly predicted by the existence of and (depending on age) duration since a serious hospital episode. Rather than forcing the hospital data to fit the conventional HE framework, a simple enumeration of the population according to recent history of hospital episodes, combined with age-dependent measures of the risk of subsequent hospital episodes, might serve to predict changes in demand for services over time.

12. Conclusions

We reviewed what is known about HE in Scotland, which is largely the report by Clark *et al.* (2004). Comparisons of the official estimates based on the GHS with England or Great Britain show that Scottish HE is worse on average, but that the ratio of HE to LE is similar; if Scots become unhealthy sooner on average they also die sooner on average. However this statement about averages does not imply that the individuals who become unhealthy sooner are the same as those who die sooner; longitudinal data are needed to examine this question.

Comparisons beyond the UK are hampered by the varying definitions of health used in different countries. Since 1995 a reasonably consistent approach has been taken within

the EU (pre-accession) countries, at the level of official statistics, and estimates of HE can be ranked, with a good deal of caution because of possible cultural differences in responding to the same question (in different languages). The Scottish estimates are outside this common framework but, with that additional call for caution, they fall very near the bottom of the European league for men, and in the bottom half for women. The trend in the ratio of HE to LE place Scotland and England in the middle of European countries, being not among those reporting expansion of morbidity (at birth), nor among those reporting compression of morbidity. However the trend in Scotland and England, which has been observed for much longer than in Europe, may be slowly declining.

Our exploration of the linked data (the Scottish Health Survey responses in 1998–99 linked to the respondents' hospital records during 1981–2004 and death registrations during 1998–2004) showed that the occurrence of serious hospital episodes is not rare by late middle age. For HE estimates, therefore, we do need a sensible definition of recovery from a spell of bad health initiated by hospitalisation. Discharge from hospital will not do because most stays in hospital are very short; this leads to HE that is over 99% of LE. Hospital records would best be supplemented by other longitudinal data to estimate HE.

However the linked data gave us a rare opportunity to study the mortality and morbidity of individual survey respondents, morbidity being defined by the first serious hospital episode after the survey. We confirmed the qualitative effect of self-assessed bad health on mortality and morbidity, which was as expected, but we were able to quantify it also, in simple survival analyses. This led us to suggest that a national or regional enumeration of recent hospital episodes, suitably classified, might be used as a predictor of future demand.

In the course of this research we investigated some topics which have not found their way into this account, and we noted some interesting questions for future work. Principally, we think that survival analysis from a survey or census baseline will be a useful tool in future, especially once the Scottish Longitudinal Survey is available, and our simple analyses could then be greatly refined using the larger and longer data set.

Acknowledgements

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