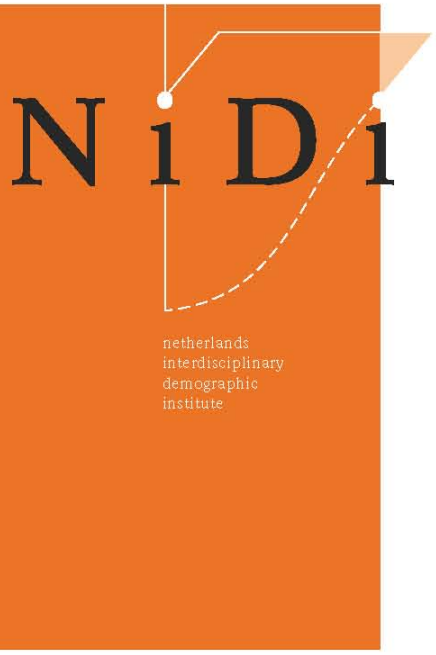
Working Paper no.: 2014/2

Nicole van der Gaag, Govert Bijwaard, Joop de Beer and Luc Bonneux

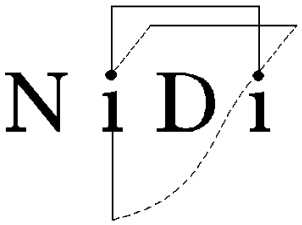
Forecasting long-term care need of elderly using a multistate projection model



Forecasting long-term care need of elderly using a multistate projection model

Nicole van der Gaag*, Govert Bijwaard*, Joop de Beer* and Luc Bonneux**
Working Paper no.: 2014/2

Draft, June 2013



* Netherlands Interdisciplinary Demographic Institute (NIDI), P.O. Box 11650, 2502 AR The Hague, The Netherlands, E-mail: gaag@nidi.nl
** Nursing Home NEVBO, The Netherlands

This paper is written in the context of the project 'Assessing Needs for Care In European Nations'(ANCIEN), funded by the European Commission in the context of the Seventh Framework Programme. The objectives of ANCIEN are to review the LTC systems in EU member states, to assess the actual and future numbers of elderly care-dependent people in selected countries and to develop a methodology for comprehensive analysis of actual and future LTC needs and provisions across European countries. The project is coordinated by the Centre for European Policy Studies (CEPS) and carried out by a consortium of research institutes composed of 21 partners.
The authors are solely responsible for the content of the Working Paper.

April 2014

Abstract

To address policy questions related to the provision of health care services in an ageing population, it is important to know how many people will face disability in (very) old age. This paper describes a generic estimation procedure for calculating incidence into disability rates from prevalence rates. As illustration we compiled two sets of scenarios of long term care need for the Netherlands. We estimated the future number of disabled elderly using a multistate projection model. For the estimation of rates we used prevalence data on disability from SHARE and mortality data from Eurostat and the Rotterdam Study of Health.

The scenarios show that demography is a strong driver of disability increase. Even if we assume incidence rates to decrease as mortality rates do, the number of persons with disability is expected to increase considerably. Adding obesity to the projections may improve the understanding of the underlying process. The strength of the method to calculate incidence rates based on prevalence rates is that the relationship between changes in mortality and disability is taken into account and that the effects of risk factors can be estimated. The improved transparency of the projections, the generic nature of the model and the applicability to all (European) countries with available prevalence data make it a useful instrument to make plausible projections of numbers of disabled elderly.

Key words: multi-state models, long-term care, projections, obesity, incidence into disability

1. Introduction

In many western European countries the number of elderly persons is increasing strongly in the coming decades as the large post-war baby boom generations are currently starting to reach the age of 65. Simultaneously, the number of the oldest old is growing rapidly as a result of increasing longevity (Oeppen & Vaupel, 2002). Although different population scenarios for Europe may project different future populations, all scenarios show significant increases in the numbers of the elderly (Eurostat, 2008, 2011; Scherbov et al.,

2008; De Beer et al, 2010; Rees et al., submitted). Since health and long term care consumption by the elderly, especially by the very old and frail, is well above average, demands of long-term care and health care expenditures are likely to increase significantly (Meerding, Bonneux et al., 1998; Meerding, Polder et al., 1998). The extent to which this demand will increase depends on the future health status of the elderly population. If the average health status will improve, long-term care need may increase to a lesser extent than the number of elderly persons. On the other hand, if disability increases strongly at very old ages, increasing life expectancies may lead to additional increases in the demand of care. The health status of the elderly is closely related to medical innovations. Improvements of health care may result in better survival, but may extend life in disability. For example, the sharp decline in acute coronary heart disease mortality has increased the number of survivors with heart failure (Bonneux et al., 1994; Peeters et al., 2003).

To address policy questions related to the provision of health care services in an ageing population, it is important to know how many people will face disability in (very) old age. Today, the after-war baby boom cohorts, starting in 1946 are reaching old age, making forecasts of the number of elderly even more important for policy makers.

The two main methods to calculate health expectancies are the Sullivan method (Sullivan, 1971) and the multistate model (Rogers et al., 1989). The Sullivan health expectancy reflects the current health of a real population adjusted for mortality levels and independent of age structure (Jagger et al., 2007). This indicator is based on prevalence data and can be used to compare the health status of an entire population at two points in time or of two different populations at the same time. Using prevalence data, the future number of disabled elderly can be estimated by projecting the future number of elderly persons and by subsequently multiplying this number by the share of the elderly that is expected to be disabled. Disability shares can be estimated by analyzing past trends in the prevalence of disability and by assuming that these trends will continue in the future. This procedure, however, does not take into account the interaction between changes in

mortality and changes in disability. If mortality rates differ between healthy and unhealthy people, changes in mortality will affect the prevalence of disability.

Multistate analysis models transitions into disability based on longitudinal data. These models can be used to estimate how many persons move from one health state to another. Several papers discuss the estimation of transition rates (for instance Pollard et al. 1990; Jung, 2006; Khoman et al., 2008; Impicciatore and Billari, 2011) The future proportion of disabled people at a certain age depends on the probability that healthy people will become disabled, on the probabilities that healthy and unhealthy people will die and on the probability that disabled people will recover. Instead of making assumptions about future proportions of disabled people one can project these proportions as the result of underlying transitions. The use of a multistate model for making scenarios requires that assumptions are made about future changes in transition rates rather than disability prevalence. Another advantage of multistate models is that they can explicitly take into account the effects of changes in risk factors on the prevalence of disability. For instance, if the probability of becoming disabled for obese people exceeds that of people with 'normal' weight, the model can be used to project the effect of changes in the prevalence of obesity on the number of disabled people. A disadvantage, however, is that the data required for these estimation are expensive to acquire and often missing. This is especially the case for studies aiming at cross national European wide comparisons.

In this paper we discuss the application of a multistate projection model to estimate long term care need according to two different sets of scenarios. We describe a generic estimation procedure for calculating incidence into disability rates based on disability prevalence rates. By taking prevalence rates as point of departure to estimate incidence rates, we take advantage of the relatively stable patterns of prevalence data compared to the more fluctuating patterns of incidence data (if available at all), while at the same time we can study the impact of different assumptions on transitions into disability. For the estimation of the rates we use prevalence data on disability from the Survey of Health, Ageing and Retirement in Europe (SHARE) together with mortality data from Eurostat and estimates of state and risk factor mortality taken from the Rotterdam Study of Health

ERGO (Hu et al., 2005). We compare the results of the incidence based scenarios with the outcomes of a model assuming constant disability prevalence. Furthermore, we show how to include risk factors into the model by taking into account the effect of obesity on the onset and development of disability. We illustrate the method for the Netherlands, but given its relatively modest data requirements it can be widely applied across (European) countries.

2. Two sets of scenarios of long term care need

There is no unique definition of disability and long term care need. We assume that the need of care depends on having at least one disability in basic activities of daily living (BADL): getting out of bed, dressing, washing, going independently to the toilet and eating without help (Katz et al., 1963). A long standing debate on compression or expansion of morbidity has been started with the seminal paper of James Fries on compression of morbidity (Fries, 1980). Recent analyses confirm an extended life free of care and in good health (Manton et al., 2008), but which goes together with increased care-dependent life, as the incidence of care is strongly age dependent (Olshansky et al., 1991). Both disability and mortality at old age are strongly related processes, determined by increasing frailty, a consequence of ageing (Mitnitski et al., 2002). In recent periods, life expectancy is increasing by decreasing mortality of the elderly (Christensen et al., 2009; Vaupel, 2010). Changes in disability confirm a longer life in good health of elderly (Cai and Lubitz, 2007; Manton et al., 2008; Reuser et al., 2010). Wear and tear is a chronological process, depending on duration of exposure, and hence a chronological process, but repair and other plastic responses to damage by wear and tear are biological processes, which may be supported by healthy lifestyles and medical technology (Christensen et al., 2009).

We developed two incidence based scenarios based on alternative assumptions about future changes in disability for the period 2008-2060. In the first scenario (CHRON) we calculate incidence into disability and mortality rates for the base year of the projections (2008) and keep these rates constant over the entire projection period. This shows the net

consequences of mortality decrease if incidence stays put at a certain age. This may be called a chronological scenario, as it assumes that incidence of disability is determined by the chronological time spent in the life course. This scenario assumes that (age related) disability and (age related) mortality are independent processes. Old age mortality moves further up to increasing ages, but incidence of old age disability stays constant at the same age. In the second incidence based scenario (BIOL) we assume that incidence rates decrease as mortality rates do assuming a strict correlation between age related mortality and age related disability. This scenario assumes that the incidence of disability and mortality are caused by the same biological aging process (Mitnitski et al., 2002). We compare the incidence based scenarios with a prevalence based scenario (PREV). The prevalence based scenario assumes that disability prevalence by age and sex will remain constant over time.

In order to examine the impact of risk factors on the future prevalence of disability we calculated a second set of scenarios consisting of three scenarios for future patterns of obesity. Obesity, i.e. a body mass index (BMI) greater than or equal to 30, increases the risk of disability often just by putting more weight on joints. The obesity scenarios are consistent with the biological scenario. That means that also for the scenarios including obesity, we assume that incidence rates decrease as mortality rates do. In the first scenario including obesity we move the prevalence of obesity at younger ages forward to older ages (scenario BMI). In the second scenario we assume that the prevalence of obesity will return to 1960 levels. This would imply that the prevalence of obesity among the elderly would be about half that in the BMI scenario (scenario LEAN). In the third obesity scenario we assume the prevalence of obesity will double (scenario FAT). For these three scenarios current prevalence of obesity at age 55 is taken as point of departure.

3. Method

3.1 The multistate projection model

In a multistate projection model the distribution of people over states is the outcome of transitions people make. For projecting the future number of disabled elderly we distinguish three states: (1) non disabled (nD), (2) disabled (D) and (3) death. There are four possible transitions between these states: incidence rates: from (1) to (2), recovery rates: from (2) to (1), and mortality rates for non disabled and disabled persons: from (1) to (3) and from (2) to (3), respectively. When risk factors are added, the number of states increases. In our obesity scenarios, we distinguish five states: (1) non-obese, non-disabled (nOnD), (2) obese, non-disabled (OnD), (3) non-obese, disabled (nOD), (4) obese, disabled (OD) and (5) death. Obviously this will increase the number of possible transitions. The number of transitions included in the model will depend on whether all theoretically possible transitions will be included. For practical purposes the number of transitions may be reduced, e.g. because reliable data are lacking or because specific transitions are assumed to be very low. In our scenarios including obesity we assume that no transitions take place between the states being obese and not obese. Thus obesity is included in the model as a time-constant risk factor. In our model we took obesity status at age 55 as point of departure, assuming that either obesity status at age 55 will not change over time, or that obesity status at age 55 determines future risks on the onset of disability and mortality.

Since we focus on the elderly aged 65 and over, we do not have to compile projections from birth onwards. In order to take into account changes in obesity prevalence at age 55, our projections start at age 55 and run to age 100+. The population for the first age group (age 55) was extracted from the EUROPOP2008 population projections (Eurostat, 2008). As a result we implicitly introduce the mortality and migration assumptions at ages younger than 55 of the EUROPOP2008 scenarios. As our scenarios cover the period 2008-2060, our projections are based on the population already alive. Therefore, the model does not need to include fertility. Moreover, since both immigration and

emigration rates tend to be low for elderly people migration is excluded from the model as well. Thus contrary to EUROPOP2008 we use a life table model of a closed population. As a consequence the results of our projections of the population aged 65+ will be slightly different from the EUROPOP2008 results.

3.2 Estimation of transition rates

For making scenarios using the multistate model we need to make assumptions about the future values of mortality rates conditional on health status (being disabled or not) and about the transition rates from being healthy to being disabled and vice versa, distinguished by age and sex. We estimate these rates from the prevalence rates of disability and the unconditional mortality rates (not distinguished by health status).

One problem in using prevalence data is that they show the net change in the proportion of disabled persons only. The proportion of disabled people is affected by both the incidence of disability (i.e. the proportion of healthy people who become disabled) and recovery (the proportion of disabled persons who become healthy again). Thus both an increase in incidence and a decrease in recovery can lead to an increase in the prevalence of disability. Since we assume that changes in prevalence are predominantly affected by changes in incidence rather than by recovery we focus on incidence and do not explicitly take into account recovery. This implies that the estimated incidence into disability refers in fact to a so-called 'net number' of disabled persons. An advantage is that the uncertain fluctuating state at the margins between disabled and non disabled is collapsed to a single incidence.

If we know the unconditional mortality rate at age *x*, the relative mortality risk of disabled persons relative to healthy persons and the prevalence of disability at age *x*, we can estimate the mortality rate of disabled persons. We assume that the relative mortality risk of disabled persons versus non-disabled persons is independent of age:

$$\mu_D(x) = r_D . \mu_{nD}(x) \qquad (1)$$

where $\mu_D(x)$ = the mortality rate of disabled persons at age x, $\mu_{nD}(x)$ = the mortality rate of non-disabled persons at age x and r_D = the relative mortality risk of disabled persons relative to non-disabled persons.

The incidence rate of disability at age x can be estimated from the difference between the prevalence at age x and age $x+1$, taking into account the mortality rate of disabled persons at age x. Thus the estimate of the disability incidence rate depends on the estimate of the mortality of disabled persons and vice versa. Therefore we use a stepwise iterative procedure.

Step 1: In the first step we calculate the start value for $\mu_D(x)$ from the total survival rate and the prevalence of disabled persons and its complement the prevalence of non-disabled persons by solving:

$$\exp(-\mu_{tot}(x)) = Q_{nD}(x)\exp(-\mu_{nD}(x)) + Q_D(x)\exp(-r_D\mu_{nD}(x)) \quad (2)$$

where $\mu_{tot}(x)$ = the total mortality rate at age x, $Q_{nD}(x)$ = the proportion of non-disabled persons at age x and $Q_D(x)$ = the proportion of disabled persons. Since we assume an exponential model for the age pattern of mortality $\exp(-\mu(x))$ equals the survival rate from age x to $x+1$.

Step 2: In the second step we calculate the value of the disability incidence rate $\theta(x)$, i.e. the transition rate from non-disabled to disabled from age x to age $x+1$ in such a way that the projected prevalence at age $x+1$ equals the observed prevalence. The prevalence at age $x+1$ can be projected by the prevalence at age x, the probability of non-disabled persons to become disabled and the probability of a disabled person at age x to be disabled at age $x+1$ (or in other words the probability to survive to age $x+1$):

$$\hat{Q}_D(x+1) = [Q_{nD}(x)P_{nD,D}(x) + Q_D(x)P_{D,D}(x)]/S(x) \quad (3)$$

where $\hat{Q}_D(x+1)$= the projected prevalence of disability at age *x+1*, $P_{i,j}(x)$ = the transition probability from state *i* to state *j* from age *x* to *x+1* and *S(x)* is the survival of all individuals from age *x* to age *x+1*:

$$S(x) = Q_{nD}(x)\left[P_{nD,nD}(x) + P_{nD,D}(x)\right] + Q_D(x)[P_{D,D}(x)] \quad (4)$$

The transition probabilities can be calculated from the transition rates as follows (see e.g. Singer and Spilerman, 1976). Since we assume no recovery, the probability of disabled persons at age *x* to be disabled at age *x+1* equals their survival rate:

$$P_{D,D}(x) = \exp[-\mu_D(x)] \ . \quad (5)$$

The probability of non-disabled persons at age *x* to remain non-disabled at age *x+1* depends on the transition from being non-disabled to disabled and on the mortality rate of non-disabled persons:

$$P_{nD,nD}(x) = \exp[-\theta(x) - \mu_{nD}(x)] \ . \quad (6)$$

The probability of the transition from non-disabled to disabled depends on both the transition rate from non-disabled to disabled and on the mortality rates of both disabled and non-disabled persons:

$$P_{nD,D}(x) = \frac{\theta(x)}{\mu_D(x)-\theta(x)-\mu_{nD}(x)}\{\exp[-\mu_D(x)] - \exp[-\theta(x) - \mu_{nD}(x)]\} \quad (7)$$

We calculate the value of $\theta(x)$ for which the projected value of the prevalence equals the observed value, i.e. $\hat{Q}_D(x+1)$= $Q_D(x+1)$ given the estimated start value of $\mu_D(x)$.

Step 3: In the third step we recalculate $\mu_D(x)$ in such a way that the projected mortality of disabled and non-disabled persons equals total mortality:

$$1 - \exp(-\mu_{tot}(x)) = \mathrm{Q_{nD}(x)}[1 - \mathrm{P_{nD,nD}(x)} - \mathrm{P_{nD,D}(x)}] + \mathrm{Q_D(x)}[1 - \mathrm{P_{D,D}(x)}] \quad (8)$$

We repeat steps 2 and 3 until we reach convergence.

3.3 BADL disability incidence rates

Using BADL disability prevalence rates, relative mortality risks and mortality rates for 2008 adopted from EUROPOP2008, we estimated incidence into disability rates and mortality rates for non-disabled and disabled persons.

To determine the age and sex specific prevalence of disability in the Netherlands, we used SHARE panel data . Since the numbers of oldest old persons in this survey are small, the prevalence at old ages shows very strong fluctuations. Therefore, the age pattern of prevalence rates is smoothed using a weighted Gompertz model (Figure 1). As expected, the prevalence of persons with at least one BADL-limitation strongly increases with age, both for males and females.

[Figure 1 about here]

A drawback of using SHARE data is that the survey does not include people living in institutions. In the Netherlands a considerable proportion of the oldest old is institutionalized. Since for most of these people being disabled is the reason why they could not stay in a private house, surveys excluding people living in institutions will lead to underestimating the prevalence of disability among elderly. Therefore we increased the SHARE estimate by a factor based on administrative data on persons who receive financial support for long term care expenses (AWBZ data). Most of these expenses cover the costs for the institutionalized population. Applying the rescaled age specific prevalence for individual ages to the Dutch population as of 1 January 2008 results in an estimate of slightly over 400 thousand elderly with BADL disability.

We used a Cox proportional hazards model to estimate the relative risks based on data from the Rotterdam study of health ERGO (Hu et al., 2005). The estimated relative mortality risk of disabled persons relative to non-disabled persons equals 1.89 for men and 1.55 for women.

Figure 2 shows the estimated incidence rates for men and women in the Netherlands on a logarithmic scale. For elderly up to the age of 80 the incidence rates of women exceed that of men. For people aged 80 or over there are hardly differences between men and women.

[Figure 2 about here]

3.4 Adding the risk factor obesity

Including the effect of risk factors in the model implies we have to take into account the differences in disability incidence rates and mortality rates by categories of the risk factor. Comparable to the model without risk factors, these rates are estimated based on the prevalence of BADL disability by risk factor status and mortality rates by health status but not distinguished by risk factor status. Thus to estimate obesity-specific BADL disability incidence and mortality we need data on obesity-specific BADL disability prevalence and mortality rates for persons with and without BADL disability (as estimated in the model without obesity).

Although SHARE covers data on both BADL disability and obesity prevalence the numbers are too small to directly infer obesity-specific BADL disability prevalence from this survey. Therefore we estimated obesity-specific BADL disability prevalence from the marginal prevalences of BADL disability and obesity using the Mantel-Haenszel odds ratio (OR) weighted by 5-year age groups. The Mantel-Haenszel OR shows the ratio of the odds of being disabled while being obese (OD/OnD) to the odds of being disabled and being not obese (nOD/nOnD). For males the odds ratio ([OD/OnD]/[nOD/nOnD]) turned out to be not significant different from 1, while for females the ratio was highly

significant. Therefore we assume that BADL disability prevalence is equally to occur among obese and non-obese males (odds ratio of 1), and more likely to occur among obese than among non-obese women by a factor of slightly over 2 (odds ratio of 2.1). Since the odds ratio is a function of the four cells of the obesity-specific BADL disability prevalence matrix (OD, OnD, nOD, and nOnD), for both sexes and all ages the four cell prevalences can be recovered from the marginal prevalences of BADL disability (D and nD) and obesity (O and nO) and the Mantel-Haenszel odds ratio.

Obesity-specific incidence and mortality is estimated such that the weighted average is equal to the total incidence and mortality using weights for obesity based on a study of Walter et al. (2009). Similar weights are assumed for males and females. The relative mortality risks by gender and obesity status are given in Table 1.

[Table 1 about here]

To estimate obesity-specific incidence and mortality rates we need the relative mortality risk r_O and the relative incidence rate i_O of persons with obesity compared to those without obesity. Both relative risks are assumed to be independent of age. Thus

$$M_{OD}(x) = r_O \,.\mu_{nOD}(x) \tag{9}$$

where $\mu_{OD}(x)$ = the mortality rate of disabled persons with obesity at age x and $\mu_{nOD}(x)$= the mortality rate of disabled persons without obesity, and we assume

$$\theta_O(x) = i_O \,.\theta_{nO}(x) \tag{10}$$

where $\theta_O(x)$= the disability incidence rate of obese persons from age x to $x+1$ and $\theta_{nO}(x)$= the disability incidence rate of non-obese persons.

The mortality rate of a non-obese disabled individual can be calculated from the mortality rate of disabled persons and the prevalence of obese and non-obese disabled persons:

$$\exp(-\mu_D(x)) = \frac{Q_{OD}(x)}{Q_{OD}(x)+Q_{nOD}(x)}\exp\left(-r_O.\mu_{nOD}(x)\right) + \frac{Q_{nOD}(x)}{Q_{OD}(x)+Q_{nOD}(x)}\exp(-\mu_{nOD}(x)) \quad (11)$$

where $Q_{OD}(x)$= the prevalence of disabled obese persons at age *x* and $Q_{nOD}(x)$= the prevalence of non-obese disabled persons. The mortality of a non-obese non-disabled individual can be calculated from:

$$\exp(-\mu_{nD}(x)) = \frac{Q_{OnD}(x)}{Q_{OnD}(x)+Q_{nOnD}(x)}\exp\left(-r_O.\mu_{nOnD}(x)\right) + \frac{Q_{nOnD}(x)}{Q_{OnD}(x)+Q_{nOnD}(x)}\exp(-\mu_{nOnD}(x)) \quad (12)$$

where $Q_{OnD}(x)$= the prevalence of non-disabled obese persons at age x and $Q_{nOnD}(x)$= the prevalence of non-obese non-disabled persons.

The disability incidence rate of a non-obese individual can be calculated from

$$\exp\left(-\theta(x)\right) = [Q_{OD}(x) + Q_{OnD}(x)]\exp\left(-i_O.\theta_O(x)\right) + [Q_{nOD}(x) + Q_{nOnD}(x)]\exp(-\theta_{nO}(x)) \quad (13)$$

The resulted obesity specific incidence rates are given in Figure 3.

[Figure 3 about here]

Both among women and men, the incidence of BADL disability among the obese is higher than among the non-obese. The higher incidence risk for obese people together with mitigated mortality rates for the obese once disabled, are consistent with the literature: "smoking kills, obesity disables" (Reuser et al., 2008, 2009, Majer et al., 2011).

4. Results of the projections

4.1 The elderly population and BADL-prevalence in 2040 and 2060

According to all scenarios, by 2040 the growth of the population aged 65+ will reach a peak of slightly over 85 per cent for women and almost 110 per cent for men (Table 2). In

the last 20 years of the projection the elderly population starts to decline slowly but by 2060 the total number of elderly persons still significantly outnumbers the size of 2008. The number of persons with at least one BADL-limitation, however, continues to grow until at least 2050. Only according to the biological scenario the predicted number of persons with BADL limitations in 2060 is less numerous than the predicted number in 2040.

[Table 2 about here]

The scenario referring to constant age and sex specific BADL incidence (scenario CHRON) projects the smallest population increase together with the largest increase in numbers of persons with BADL disability as well as BADL prevalence. Assuming incidence rates decreasing similar to mortality rates (scenario BIOL) significantly lowers the estimates of BADL prevalence. Thus if incidence rates decrease similar to mortality rates, the need of care will increase less strongly than the increase in the number of elderly people. The CHRON scenario shows that if disability incidence rates would remain the same, the decline of mortality rates will result in an increase of the percentage of disabled persons, even though the mortality rates of disabled persons exceed those of healthy people.

In absolute numbers the expected growth in disability of females outnumbers that of males, while in relative terms growth indices for males exceed those of females. By 2060 the expected numbers of persons with BADL disability vary for females from 432 to 708 thousand, corresponding to a growth of 53 to 151 per cent. For males, the numbers vary from 246 to 400 thousand, corresponding to a growth of 104 to 233 per cent.

If we compare the results of the incidence based scenarios with the prevalence based scenario (PREV), the differences between the PREV and CHRON scenario are limited. Nevertheless, the CHRON scenario projects in total 37 thousand more persons with BADL disability in 2040 and 67 thousand more in 2060 compared to the PREV scenario. The differences with the BIOL scenario are considerable. While the PREV and CHRON

scenarios predict a significant increase in BADL prevalence between 2008 and 2060, the BIOL scenario predicts a stable pattern (for males) or small decline (for females).

Although in absolute numbers of persons with BADL disability and in terms of BADL prevalence the different scenarios show different results, the changes over time in age patterns are highly similar for all scenarios. Figure 4 presents the age pyramid for 2008 and 2060 for the CHRON scenario, and Figure 5 the pyramids for the years 2040 and 2060 for the BIOL scenario. These figures clearly show the ongoing population ageing and the correspondingly expected increase in the number of BADL-disabled persons.

[Figures 4 and 5 about here]

4.2 Adding obesity to the scenarios

A comparison of the results of the three obesity scenarios (BMI, LEAN and FAT) with the BIOL scenario illustrates the effect of possible changes in the prevalence of obesity. The BMI scenario shows that if current obesity prevalence at age 55 will remain stable in the future, the overall prevalence of obesity among the elderly will increase from 15.2 in 2008 to 20.3 in 2060. Comparing the results of the BMI scenario with the scenario BIOL, we may conclude that this will go together with a small increase of BADL prevalence (Table 3). If obesity prevalence doubles (the FAT scenario) or halves (the LEAN scenario), compared to the BMI scenario in the long run about 60,000 persons with BADL limitations more, or 30,000 less are projected.

[Table 3 about here]

Adding risk factors may improve the understanding of the underlying process. The results of the BIOL and LEAN scenario for example are highly similar. Therefore we might conclude that one possible condition for the BIOL scenario to come true, is that the prevalence of obesity should be reduced by 50 per cent. Or, alternatively, the BIOL

scenario may be considered too optimistic given current patterns and future prospects of obesity.

5. Discussion

As a result of population ageing in the European Union the numbers of dependent elderly will increase. The need of care depends on disabilities in the basic activities of daily living (BADL): getting out of bed, dressing, washing, going independently to the toilet and eating without help. Around 2040 the numbers of people aged 65+ will reach its peak in most European countries. If one assumes that the prevalence of disability will not change, by then the need of care in the Netherlands will be more than doubled. Although after 2040 the growth of the elderly population is expected to start to decline, the need of care will continue to increase for several more years given the continuing increase of the average age of the elderly. It is questionable, however, whether BADL disability prevalence will remain constant.

Generally, it is expected that mortality rates will continue to decline. Since disability and mortality are related one may expect that the prevalence of disability will change as well. Disability and mortality are related in several ways. First, trends in medical progress that affect mortality may be expected to affect disability as well. Second, risk factors that affect both mortality and disability, such as the prevalence of obesity or smoking, may be expected to change over time. Moreover, these risk factors may affect mortality and disability in a different way. Furthermore, mortality rates may differ between healthy and disabled persons. In order to take these interdependencies into account in making projections, it is necessary to use a multistate model. A multistate model projects the future number of disabled persons on the basis of assumptions about the future changes in disability incidence rates, i.e. the transition rate from being healthy to being disabled.

In principle, incidence rates can be estimated from panel studies such as SHARE. The samples in successive SHARE rounds, however, are too small to estimate transition rates. Therefore this paper describes an estimation procedure for calculating incidence

estimated from prevalence rates and mortality rates. Data on the prevalence of disability are obtained from the Survey of Health, Ageing and Retirement in Europe (SHARE). The benefit of using this data source is that it provides data on disability for many European countries. Mortality rates are obtained from Eurostat (2008). We illustrated the estimation procedure and the multistate method for two sets of scenarios. The first set is based on assumptions about the relationship between changes in mortality and changes in the incidence of disability. The second set includes the risk factor obesity and covers additional assumptions about changes in the prevalence of obesity. The scenarios show that demography is a strong driver of disability increase. Even in the most optimistic scenario where we assume incidence rates to decrease as mortality rates do (the scenario BIOL), the number of persons with BADL disability is expected to increase considerably. Adding risk factors to the projections may improve the understanding of the underlying process. The results of the scenario where we assume a strong reduction of obesity among the elderly (the LEAN scenario) are highly similar to the BIOL scenario. Therefore we either may conclude that the prevalence of obesity should be reduced by 50 per cent for the BIOL scenario to come true, or that the BIOL scenario is too optimistic given current patterns of obesity.

The strength of the method is that the relationship between changes in mortality and disability is taken into account and that the effects of risk factors on both mortality and disability can be estimated. This may improve the transparency of the projections. The weakness of the method is that it is necessary to make several simplifying assumptions. For example, the estimation of incidence rates on the basis of prevalence data ignores recovery. However, this is not necessarily a weakness. As the transition of non-disabled to disabled occurs in a volatile and fluctuating chronic process, at the margins of that process, incidence and recovery occur frequently as a consequence of random fluctuations. As a result, incidence of chronic disease is often inconsistent with prevalence. Prevalence data, on the other hand often show much more stable patterns. Another drawback is that in estimating incidence rates the distinction between age effects and cohort effects is ignored. Furthermore, the effect of risk factors was illustrated on the basis of assumptions about changes in the prevalence of obesity rather than about

transition rates between the two distinguished states non-obese and obese. Nevertheless the improved transparency of the projections, the generic nature of the model and the applicability to all countries with available disability prevalence data, make this method a useful instrument to make plausible projections of numbers of disabled elderly.

References

Bonneux, L., Barendregt, J. J., Meeter, K., Bonsel, G. J., & van der Maas, P. J. (1994). Estimating clinical morbidity due to ischemic heart disease and congestive heart failure: the future rise of heart failure. *Am J Public Health, 84*(1), 20-28.

Cai, L., & Lubitz, J. (2007). Was there compression of disability for older Americans from 1992 to 2003? *Demography, 44*(3), 479-495.

Christensen, K., Doblhammer, G., Rau, R., & Vaupel, J. W. (2009). Ageing populations: the challenges ahead. *Lancet, 374*, 1196-1208.

De Beer, J., Van der Gaag, N., Van der Erf, R., Bauer, R., Fassmann, H., Kupiszewska, D., Kupiszewski, M., Rees, P., Boden, P., Dennett, A., Jasińska, M., Stillwell, J., Wohland, P., De Jong, A., Ter Veer, A. Roto, J., Van Well, L., Heins, F., Bonifazi, C. and Gesano, G (2010). *Demographic and migratory flows affecting European regions and cities*. Final Report DEMIFER. The ESPON 2013 Programme, Applied Research Project 2013/1/3. Online at: http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/demifer.html.

Eurostat (2008). Population projections 2008-2060 - from 2015, deaths projected to outnumber births in the EU27. News release No. 119/2008, 26/8/2008.

Eurostat (2011). Population projections - Web article on results of Europop2010. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Population_ projections.

Fries, J. F. (1980). Aging, natural death, and the compression of morbidity. *N Engl J Med, 303*(3), 130-135.

Hu, F. B., Willett, W. C., Stampfer, M. J., Spiegelman, D., & Colditz, G. A. (2005). CALCULATING DEATHS ATTRIBUTABLE TO OBESITY. *Am J Public Health, 95*(6), 932-.

Impicciatore, R. & Billari, F. (2011). MAPLES: A general method for the estimation of age profiles from standard demographic surveys (with an application to fertility). *Demographic Research, 24(29)*, 719-748.

Jagger, C., Cox, B., Le Roy, S. (2007). Health expectancy calculation by the Sullivan method: a practical guide. 3rd edition [on line]. European Health Expectancy Monitoring Unit, France. Available from http://www.ehemu.eu/pdf/Sullivan_guide_final_jun2007.pdf.

Jung, J. (2006). Estimating Markov Transition Probabilities between Health States in the HRS Dataset. Paper Indiana University - Bloomington.

Katz, S., Ford, A. B., Moskowitz, R. W., Jackson, B. A., & Jaffe, M. W. (1963). Studies of Illness in the Aged. the Index of BADL: a Standardized Measure of Biological and Psychosocial Function. *JAMA, 185*, 914-919.

Khoman, E., Mitchell, J. & Weale, M. (2008). Incidence-based estimates of life expectancy of the healthy for the UK: coherence between transition probabilities and aggregate life-tables. *J. R. Statistical Society A., 171, Part 1*, pp 203-222.

Majer, I. M., W. J. Nusselder, J. P. Mackenbach, and A. E. Kunst (2011). Life expectancy and life expectancy with disability of normal weight, overweight, and obese smokers and nonsmokers in Europe. Obesity DOI, 10.1038/oby.2011.46.

Manton, K. G., Gu, X., & Lowrimore, G. R. (2008). Cohort Changes in Active Life Expectancy in the U.S. Elderly Population: Experience From the 1982â€“2004 National Long-Term Care Survey. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 63*(5), S269-S281.

Meerding, W. J., Bonneux, L., Polder, J. J., Koopmanschap, M. A., & van der Maas, P. J. (1998). Demographic and epidemiological determinants of healthcare costs in Netherlands: cost of illness study. *Bmj, 317*(7151), 111-115.

Meerding, W. J., Polder, J., Bonneux, L., Koopmanschap, M., & van der Maas, P. (1998). Health-care costs of ageing. *Lancet, 351*(9096), 140-141.

Mitnitski, A. B., Graham, J. E., Mogilner, A. J., & Rockwood, K. (2002). Frailty, fitness and late-life mortality in relation to chronological and biological age. *BMC Geriatr, 2*, 1.

Oeppen, J., & Vaupel, J. W. (2002). Demography. Broken limits to life expectancy. *Science, 296*(5570), 1029-1031.

Olshansky, S. J., Rudberg, M.A., Carnes, B.A., Cassel, B.A., Brady, J.A. (1991). Trading off longer life for worsening health: the expansion of morbidity hypothesis. *journal of ageing and health, 3*, 194-216.

Peeters, A., Bonneux, L., Barendregt, J. J., & Mackenbach, J. P. (2003). Improvements in treatment of coronary heart disease and cessation of stroke mortality rate decline. *Stroke, 34*(7), 1610-1614.

Pollard J.H., Golini, A. & Milella, G. (1990). On the use of health surveys for estimating transition rates for morbidity processes. Paper presented at the International Conference "Health, Morbidity and Mortality by Causes of Death". Vilnius (Lithuania).

Rees, P., Zuo, C., Wohland, P., Jagger, C., Norman, P., Boden, P. & Jasinska, M. (submitted). Projections of population, health, labour force and households in localities in Northern England.

Reuser, M., Bonneux, L., & Willekens, F. (2008). The burden of mortality of obesity at middle and old age is small. A life table analysis of the US Health and Retirement Survey. *Eur J Epidemiol, 23*(9), 601-607.

Reuser, M., Bonneux, L., & Willekens, F. (2010). The duration of cognitive impairment in the U.S. Health and Retirement Study. A multistate life table analysis. *Submitted*.

Reuser, M., Bonneux, L. G., & Willekens, F. J. (2009). Smoking kills, obesity disables: a multistate approach of the US Health and Retirement Survey. *Obesity (Silver Spring), 17*(4), 783-789.

Rogers, A., Rogers, G. & Branch, L.G. (1989). A Multistate Analysis of Active Life Expectancy. *Public Health Reports, 104 (3)*, 222-226.

Sanderson, W. C. & Scherbov, S. (2010). Remeasuring Aging. *Science*, 329, September 2010, 1287-1288.

Scherbov, S., Mamolo, M & Lutz, W. (2008). Probabilistic Population Projections for the 27 EU Member States Based on Eurostat Assumptions. *European Demographic Research Paper, 2.*

Singer and Spilerman (1976). The representation of social processes by Markow models. *American Journal of Sociology 82*, 1–54.

Sullivan, D.F. (1971). A single index of mortality and morbidity. *HSMHA Health Reports, 86*:347-354.

Vaupel, J. W. (2010). Biodemography of human ageing. *Nature, 464*.

Walter, S., A. Kunst, J. Mackenbach, A. Hofman and H. Tiemeier (2009). Mortality and disability: the effect of overweight and obesity. *International Journal of Obesity, 33*: 1410–1418.

TABLES

Table 1 Obesity-specific mortality

Relative mortality risks (RR) by ADL disability and obesity											
	RR mort by gender (ERGO)			RR mort by obesity (Walter)			RR mort by gender and obesity (ERGOxWalter)				
							males			females	
	males	females		nO	O		nO	O		nO	O
nD	1	1	nD	1	1.11	nD	1	1.11	nD	1	1.11
D	1.89	1.55	D	1	0.91	D	1.89	1.72	D	1.55	1.41

Table 2 Scenario results, females, the Netherlands

Netherlands						
Females		Pop 65+	Pop Index	BADL	BADL Index	BADL prevalence
2008		1,375,866	100	282,261	100	20.5
2040	PREV	2,546,779	185	600,982	213	23.6
	CHRON	2,543,595	185	618,229	219	24.3
	BIOL	2,563,847	186	456,985	162	17.8
2060	PREV	2,485,054	181	676,227	240	27.2
	CHRON	2,478,005	180	707,918	251	28.6
	BIOL	2,523,151	183	431,828	153	17.1
Males						
2008		1,038,961	100	120,426	100	11.6
2040	PREV	2,152,316	207	322,462	268	15.0
	CHRON	2,145,895	207	342,289	284	16.0
	BIOL	2,169,848	209	251,813	209	11.6
2060	PREV	2,115,557	204	364,945	303	17.3
	CHRON	2,101,625	202	400,472	333	19.1
	BIOL	2,151,891	207	246,006	204	11.4

Table 3 Scenario results BMI, LEAN and FAT scenarios

Netherlands							
Total		Pop 65+	Pop Index	BADL	BADL Index	BADL prevalence	Obesity prevalence
2008		2,414,827	100	402,688	100	16.7	15.19
2040	BIOL	4,733,695	196	708,798	176	15.0	-
	BMI	4,726,792	196	728,007	181	15.4	20.27
	LEAN	4,736,872	196	703,513	175	14.9	11.25
	FAT	4,706,628	195	776,986	193	16.5	38.43
2060	BIOL	4,675,042	194	677,834	168	14.5	-
	BMI	4,664,781	193	704,764	175	15.1	20.32
	LEAN	4,681,026	194	673,765	167	14.4	10.13
	FAT	4,632,290	192	766,752	190	16.6	40.92

FIGURES

Figure 1 BADL prevalence by gender

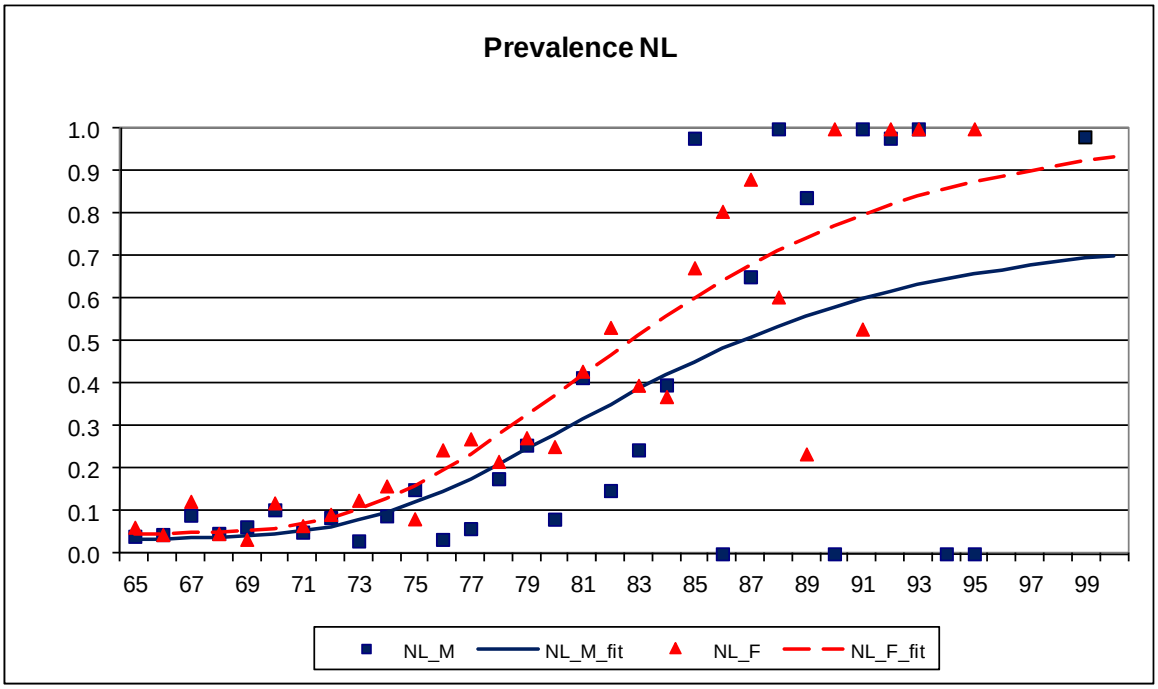


Figure 2 Disability incidence rates by gender

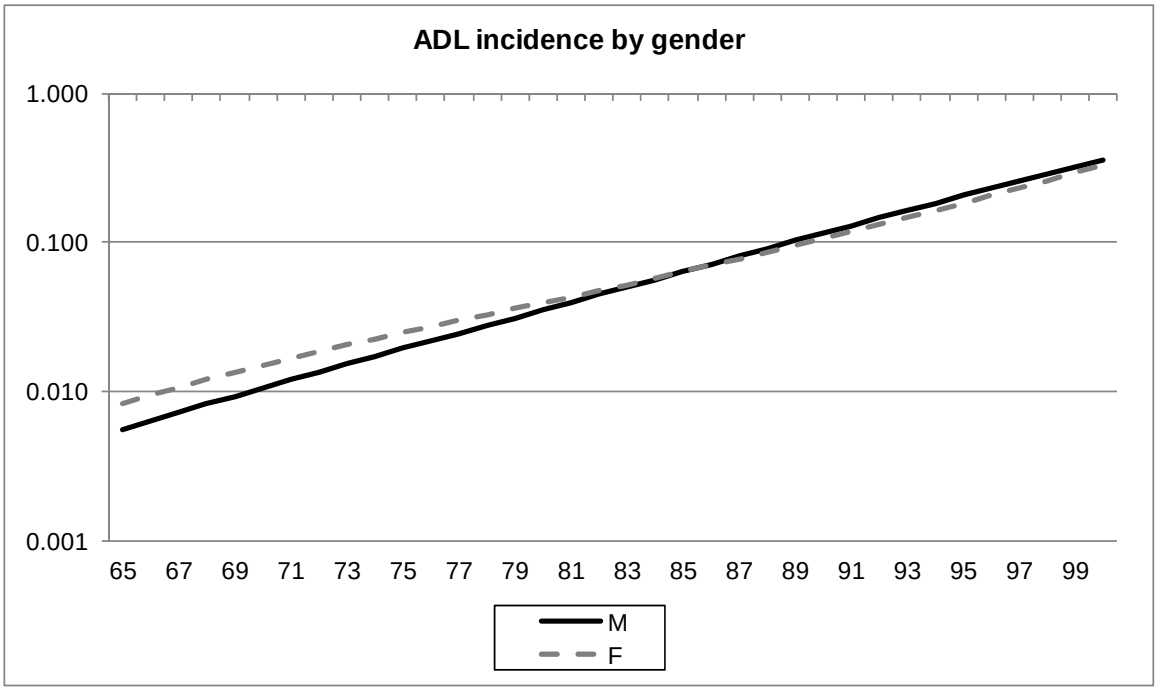
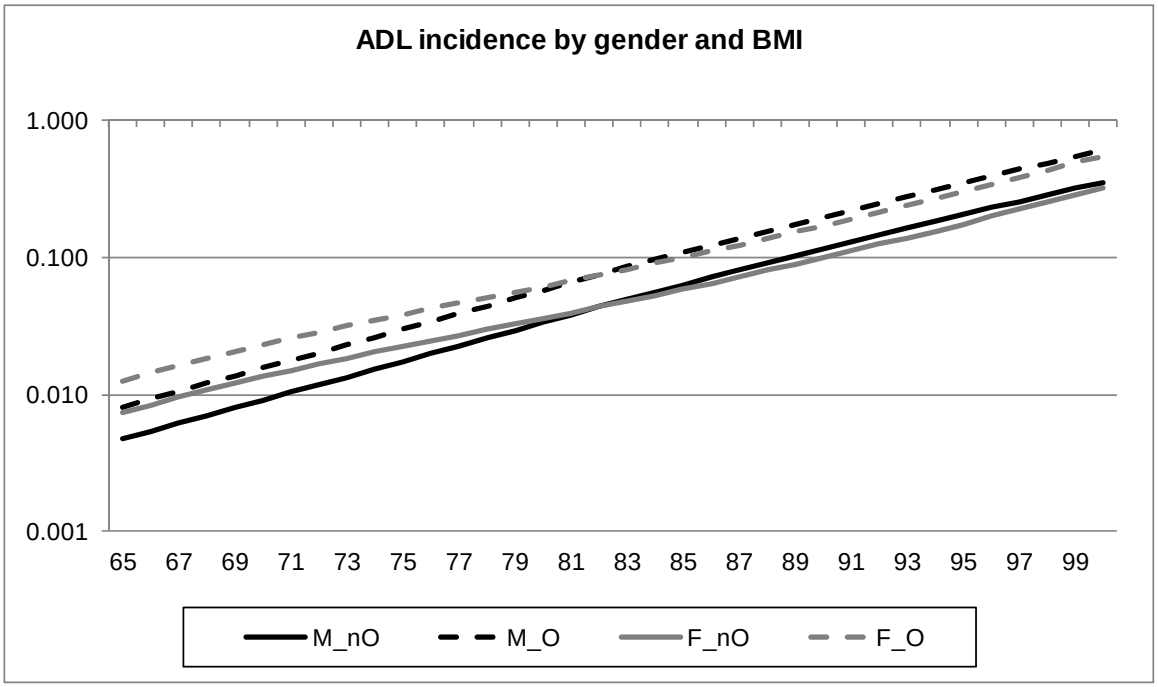


Figure 3 Incidence conditional on obesity



M_nO: males, not-obese
M_O: males, obese
F_nO: females, not-obese
F_O: females, obese

Figure 4 Age pyramids, 2008 and CHRON 2060

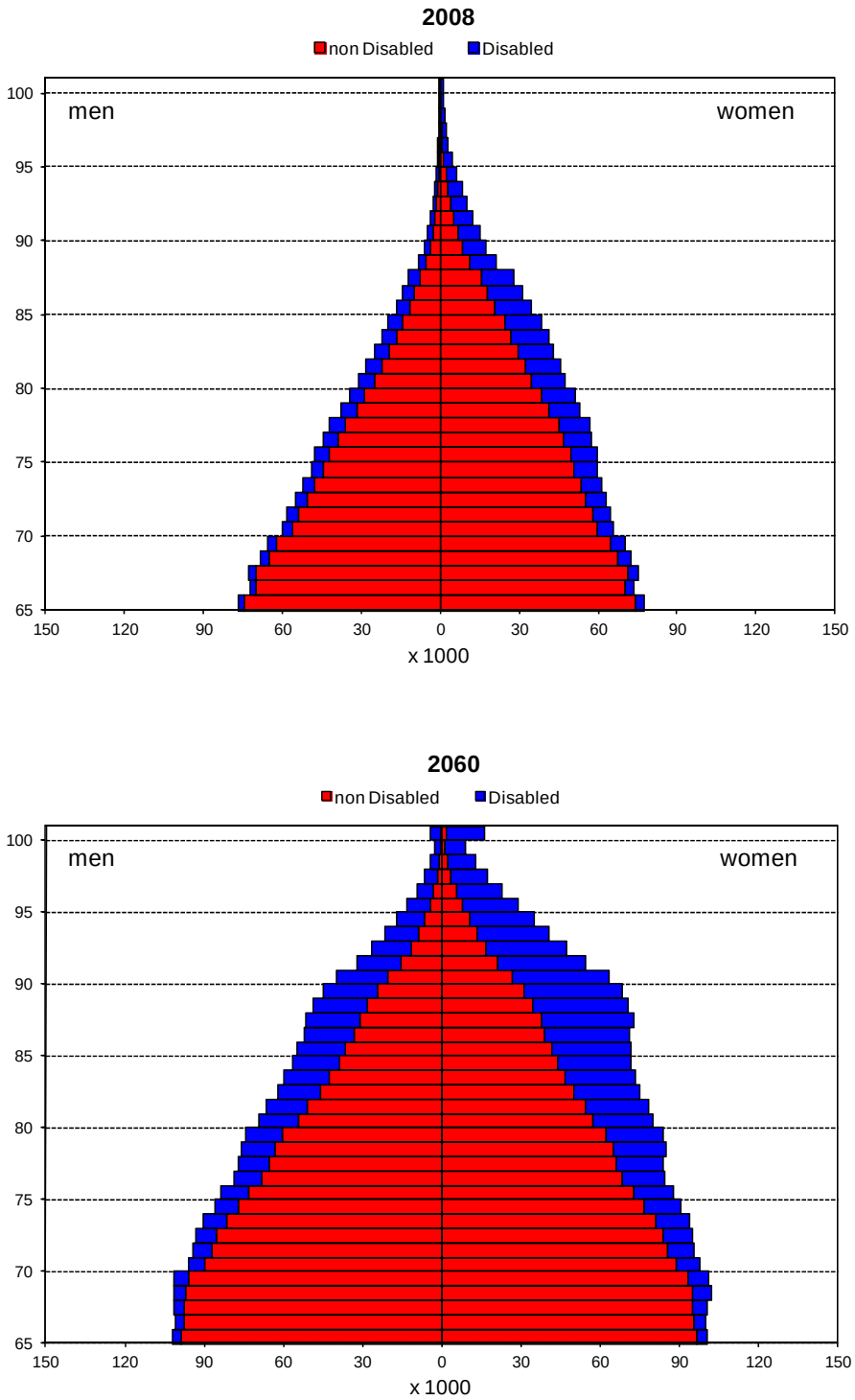
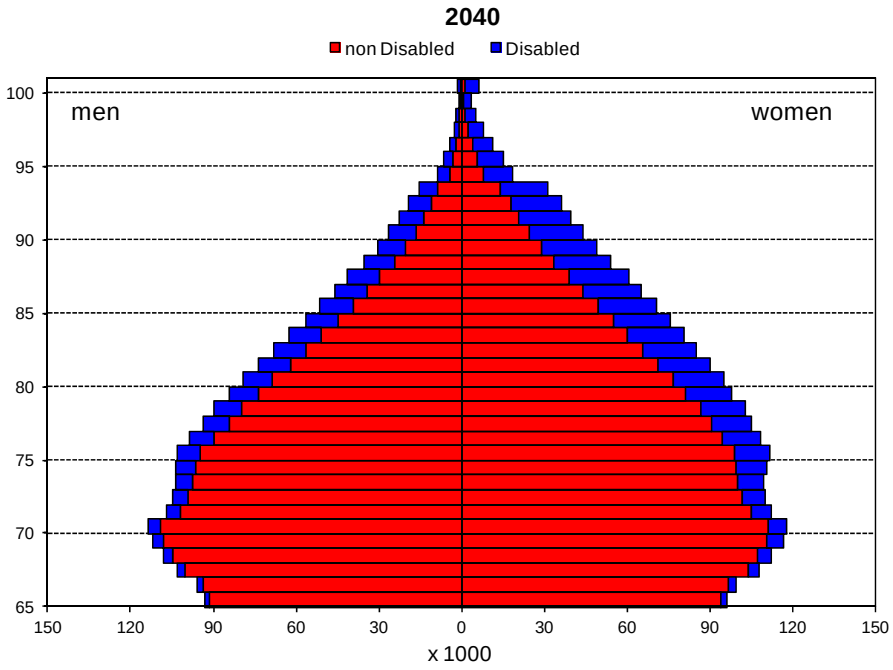
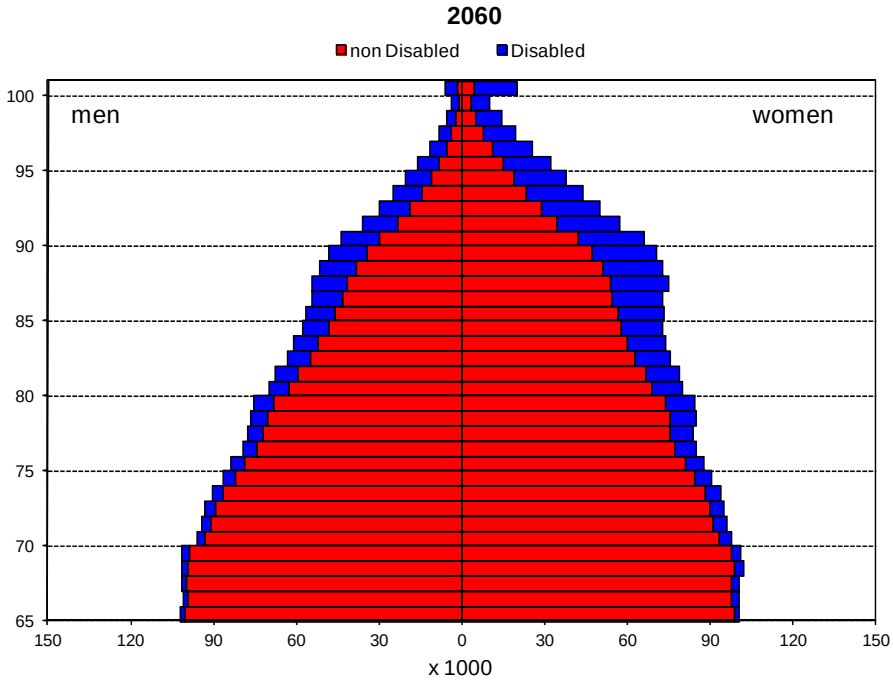


Figure 5 Age pyramids, BIOL 2040 and 2060





To address policy questions related to the provision of health care services in an ageing population, it is important to know how many people will face disability in (very) old age. This paper describes a generic estimation procedure for calculating incidence into disability rates from prevalence rates. As illustration we compiled two sets of scenarios of long term care need for the Netherlands. We estimated the future number of disabled elderly using a multistate projection model. For the estimation of rates we used prevalence data on disability from SHARE and mortality data from Eurostat and the Rotterdam Study of Health.

The scenarios show that demography is a strong driver of disability increase. Even if we assume incidence rates to decrease as mortality rates do, the number of persons with disability is expected to increase considerably. Adding obesity to the projections may improve the understanding of the underlying process. The strength of the method to calculate incidence rates based on prevalence rates is that the relationship between changes in mortality and disability is taken into account and that the effects of risk factors can be estimated. The improved transparency of the projections, the generic nature of the model and the applicability to all (European) countries with available prevalence data make it a useful instrument to make plausible projections of numbers of disabled elderly.

The Netherlands Interdisciplinary Demographic Institute (NIDI) is an institute for the scientific study of population. NIDI research aims to contribute to the description, analysis and explanation of demographic trends in the past, present and future, both on a national and an international scale. The determants and social consequences of these trends are also studied.

NIDI is a research institute of the Royal Academy of Arts and Sciences (KNAW).