Revue Quetelet/Quetelet Journal
Vol. 4, n° 1, avril 2016, pp. 29-56
DOI : 10.14428/rqj2016.04.01.02

Mortality risk by living arrangements for the elderly Belgian population

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Résumé

Objectifs : Le risque de décéder aux âges élevés est associé avec l'état matrimonial, mais également avec la situation de ménage de la personne considérée (avec qui une personne vit). Cette étude analyse comment l'association entre situation de ménage et risque de décéder varie en fonction de l'âge et du sexe. Données et méthodes : Nous utilisons des données extraites du Registre national belge concernant la situation de ménage de plus de 3 millions de personnes âgées de 60 ans et plus, observées du 1er janvier 1991 au 31 décembre 2010. Tout d'abord nous calculons et comparons les probabilités annuelles de décéder pour les personnes selon les différentes situations de ménage. Ensuite nous construisons des tables de mortalité multi-états en utilisant les probabilités annuelles de transition entre différentes situations de ménage et ce, afin de reconstituer les trajectoires de situation de ménage. Résultats : Nos résultats confirment l'effet protectif associé au fait de vivre en couple marié, mais ils montrent également que vivre seul aux âges plus élevés devient favorable à la survie. Un croisement apparaît entre les risques de décéder de ceux vivant seuls et ceux vivant avec d'autres personnes, mais pas avec leur conjoint. Toutefois de fortes différences ressortent selon le sexe. Enfin vivre en ménage collectif est largement défavorable pour la survie par comparaison à tous les types de ménages privés et ce, pour les deux sexes. Discussion : La façon dont le risque de décéder varie selon la situation de ménage est différente selon le sexe et diminue avec l'âge de façon relative. Parmi d'autres explications, le rôle sélectif de l'état de santé est majeur, tout comme le soutien du conjoint qui est, dans la plupart des cas, le premier donneur de soin. Selon cette perspective, la différence d'espérance de vie en santé entre

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hommes et femmes et la différence d'âges entre conjoints pourraient contribuer à expliquer les différences du risque de décéder selon la situation de ménage entre les hommes et les femmes. Nos résultats sont importants dans le cadre des politiques sociales relatives aux personnes âgées et plus particulièrement pour l'évaluation des besoins futurs de nos populations vieillissantes.

Mots-clés
Risque de décéder, situation de ménage, personnes âgées, différences par sexe.

Abstract
Objectives: Mortality risk in old age is associated with both marital status and living arrangements (with whom a person is living). This study analyses how the association between living arrangements and mortality risk varies by age and gender. Data and methods: We use a dataset extracted from the Belgian national register for the population aged 60 years and over, from 1 January 1991 to 31 December 2010, that includes more than three million persons and describes their living arrangements. First we compute and compare single-year probabilities of death for each living arrangement. Then, in order to recompose the living arrangement trajectories, we construct multistate life tables using annual probabilities of the transitions between successive living arrangements. Results: Our results confirm the protective effect of living with a spouse, and also show that at older ages living alone becomes advantageous. A crossover occurs in the mortality risks of those living alone and those living with others (not with a spouse), but large differences appear between the genders. Institutional living arrangements are largely detrimental for survival compared with private living arrangements for both genders. Discussion: The variation of mortality risk by living arrangements is gender-specific and decreases by age in relative terms. Among possible explanations, the selective role of health is paramount, as well as the presence of a spouse, who is the primary caregiver in most cases. According to this perspective, the gender gap in healthy life expectancy and the age difference between spouses contribute to explaining the gender differences. Our findings are highly relevant to social policies and the social discourse pertaining to the future needs of the elderly within the context of population ageing.

Keywords
Mortality risks, living arrangements, elderly, gender gap.

Introduction

This article addresses the association between living arrangements (LAs) and mortality risks for the elderly population of Belgium. LAs describe the social environment of individuals, specifically with whom a person lives: a partner, others, alone, or in a collective household. It is well established that marital status is associated with a variation in mortality risks

(Manzoli *et al*., 2007; Martikainen *et al.,* 2005; Rendall *et al*., 2011; Robards *et al*., 2012). Fewer researchers have addressed the variation in mortality risks by LAs, and most of their studies have either contrasted large groups of LAs (Davis *et al.*, 1992) or described specific LAs such as living alone (Kandler *et al*., 2007), in an institution (Breuer *et al*., 1998), or in a religious community (Luy, 2003).

In this contribution we focus on the association between LAs and mortality risks, also distinguishing by marital status where appropriate. The use of a large register-based dataset of people aged 60 years and above observed over a period of 20 years, which allows us to investigate the LAs of older men and women in greater detail including the related mortality risk by single year of age up to 100 years, makes our study original. A previous study of the same population analysed mortality risks during the year 2002, following the 2001 census, and reported significant differences associated with LAs (Herm *et al*., 2015). However, it gave only a broad outline of the variation in this association by age and gender. The present contribution describes these differences in more detail by pooling data over a period of 20 years.

Background

Many researchers have claimed that marriage has a protective role in relation to longevity (Hu, Goldman, 1990; Goldman *et al.,* 1995; Valkonen *et al*., 2004; Martikainen *et al*., 2005; Henretta, 2010; Zhu, Gu, 2010; Rendall *et al*., 2011; Drefahl, 2012; Staehelin *et al*., 2012). A comprehensive review of studies dealing with this relationship revealed that 26 out of 53 of them reported marriage or support from a spouse as a significant protective factor against mortality (Manzoli *et al*., 2007). In most western countries studies of the relationship between marital status and mortality have showed a trend towards increasing excess mortality in the 1980s and 1990s among single men compared with married men, and among single, divorced and widowed women compared with married women (Valkonen *et al.*, 2004). The advantage of being married has been demonstrated to be stronger for men compared with women, whereas excess mortality for divorced and single individuals, both men and women, persisted up to the age of 80 (Staehelin *et al.* 2012).

Marriage legally binds two individuals and implies definite obligations on the part of spouses. Generally, these obligations include mutual support

such as caregiving in the case of deteriorating health. However, the degree to which legal marital status can predict various aspects of that support, and their relationship to mortality risks, has decreased over time in modern European societies. An increasing number of married people do not live together, whereas more and more people live conjointly without being married and could benefit similarly to married people. For these reasons LAs may have a higher degree of relevance to wellbeing and the availability of concrete support compared with marital status among older people. LAs not only better reflect the *de facto* situation in relation to the availability of support, but a change of LAs is often linked to health deterioration, unlike marital status. Accordingly, LAs may capture in a different and complementary way differences in the mortality risk related to family and co-residence with regard to the availability of support and primary caregiving in old age (Koskinen *et al*., 2007; Staehelin *et al*., 2012; Herm *et al.*, 2015). Complementing LAs with marital status can show more explicitly with whom a person lives, the family links with co-residents, and the kind of support that might be expected. Therefore the extended LA typology we propose contributes to a better understanding of the variation in mortality risk associated with co-residence.

Compared with the impact of marital status, there is less research on the association between LAs and mortality risk, and only a few studies included the LAs of older persons in their analysis. Furthermore, such studies usually group older persons together without showing differences in the mortality risk at the oldest ages. Early research by Davis *et al.* (1992) on the survival of U.S. adults up to age 75 living alone, with a spouse, or with others, showed no evidence of LAs exerting a specific influence on mortality beyond that of marital status. Only a slightly higher mortality risk was identified for men who lived alone or with others compared with men who lived with a spouse, and no effect of LAs was observed among women. In contrast, more recent research by Koskinen *et al.* (2007) on the Finnish adult population (aged 30 and over) demonstrated large mortality differences by LAs. The spouse of an older person whose health deteriorates is usually his or her primary caregiver (Freedman *et al*., 2014). However, the positive effects of healthy behaviour and wellbeing resulting from co-residence are not directly attributable to the presence of a spouse, as the quality of the relationship and other factors may vary, and another adult in the household may support a healthy lifestyle similarly to a spouse (Anson, 1989). Studies demonstrating the longevity advantage of being married and living with a spouse often consider unmarried individuals as a homogeneous group (Liu, Rezcek, 2012). However, the unmarried who live alone and those who live with others have different

mortality risks, which remain hidden when the two groups are not considered separately (Herm *et al*. 2014). Among the various LAs, living alone has attracted relatively more research interest in connection with the effects of loneliness, social support and health behaviours on mortality risks (Joutsenniemi *et al*., 2006; Koskinen *et al*., 2007). These studies show that living alone is generally associated with a higher health and mortality risk at the younger and mid-adult ages. The mortality risk associated with institutional LAs (e.g. nursing homes) has received more attention than that associated with private LAs (Breuer *et al.,* 1998; Raines, Wight, 2002; Flacker, Kiely, 2003). Some studies have compared mortality associated with these two types of LAs (Grundy, 2011; Herm *et al.*, 2014) and demonstrated a higher mortality risk and larger gender gap in mortality for institutional LAs, particularly nursing homes.

Some previous studies indicated that the links between LAs and mortality risks are age- and gender-specific. Among older people, living alone is a risk factor for men but not particularly for women (Kandler *et al.,* 2007). Koskinen *et al.,* (2007) suggested that a gender-age interaction exists between survival and LAs, and that the gender gap becomes less important at older ages. The excess mortality risk among men living alone has been found to be remarkably high from the mid-adult years (Martikainen *et al*., 2005) through age 65 to 80 but decreases with increasing age and disappears after age 80 (Staehelin *et al.,* 2012; Poulain, Herm, 2015). Old Belgian men have a better chance of living longer when they are living with a spouse, while old women's lives are prolonged by living alone (Herm *et al*., 2015). At earlier old ages being married and living with a spouse is also the most favourable LA for women. But with increasing age mortality between the different LAs converges and could even cross over at the oldest ages (Poulain, Herm, 2015). No research has yet demonstrated such a phenomenon explicitly. While the mortality patterns by LAs are gender-specific, convergence and crossover may occur at different ages for men and women or not occur at all for one of the genders.

The current study contributes to the debate on the relationship of mortality risk to both marital status and LAs. It complements the rather limited number of studies on interactions between mortality risks and LAs at the oldest ages. In particular, it broadens the knowledge on old-age mortality, demonstrating gender differences in the mortality risk in older age by LAs and identifying which LA trajectories are associated with a longer lifespan.

Research questions and hypotheses

This study investigates how age-specific probabilities of death are associated with LAs in old age, and distinguishes between the marital statuses of those living alone. Health is closely related to mortality risk and is also an important factor in the choice of LAs (Börsch-Supan *et al*., 1996; Grundy, 2001). In the context of deteriorating health in older age, the association between LAs and mortality risk is expected to be gender-specific and to vary over the later phases of the life course. As a consequence, a mortality crossover between the pairs of LAs might emerge.

Our hypotheses are the following:

- Significant differences exist between mortality risks by LAs. In a given LA, additional variation emerges when marital status is taken into account, i.e. single or widowed persons do not exhibit the same mortality risk when they are living alone, with others in private LAs, or in institutional LAs (H1).
- We expect that the association of mortality risk with LAs is gender-specific and more specifically that living with a spouse or other persons is relatively more favourable for men, while living alone at the older ages favours women's survival (H2).
- As the association between mortality risk and LAs varies by age, this variation could result in convergence for some pairs of LAs with increasing age and might even cross over at a certain age (H3). These crossover points in mortality risk might be gender-specific and occur at different ages for men and women.

Data sources and methods

To answer our research questions we use data extracted from a large Belgian dataset, the national population register *Registre National*, which has been operational since 1988 and considered reliable for demographic statistical purposes since 1991 (Poulain, 2010). Our database covers the Belgian population aged 60 and over and includes information on all individual demographic events that have occurred since 1 January 1991: marriage, divorce, widowhood, change of place of residence, change in household composition including entry into an institution, and death. The household information identifies individuals who are living together as well as their family link with the household person of reference. That information enables identification of the LAs of a given person at any time

since 1991. For the analysis of associations between LAs and mortality risk we excluded those who immigrated from abroad or emigrated after 1991.

The main advantage of register-based data with regard to the analysis of the relationship between LAs and mortality is the availability of continuous information on all changes of LAs occurring during the observation period. Compared with censuses and surveys the register includes information on the exact dates of demographic events, and it enables all such events to be linked with the socio-demographic characteristics of the individuals involved. More broadly, the advantage of register-based data derives from exhaustive continuous coverage of the population of interest, which allows specific groups of the older population to be compared, and possible associations between very detailed LAs and mortality risks among the oldest olds to be disclosed.

The accuracy of the data included in that administrative database is generally good even if such data might present a situation that differs slightly from the *de facto* LA situation (Poulain, Herm, 2013). Such errors mainly relate to institutional LAs, which for the elderly usually means living in a nursing home. New admissions to a nursing home are often only registered three to six months after the fact, and as a result, some deaths may not be registered as deaths in a nursing home. Such a delay in registration results in a reduced proportion of individuals living in a nursing home at the end of their life, and in an accordingly lower mortality risk among the institutionalised elderly. However, as our results show (Herm *et al*., 2014), the mortality risk in nursing homes is generally higher than in private LAs and consequently this bias merely underestimates the mortality risk.

The LA typology used in this study includes four broad categories of individuals. The analysis focuses on the most frequent LAs in old age, which are as follows:

- Living with a spouse, with a further distinction for those living with only a spouse, with a spouse and children, or with a spouse and any other person.
- Living alone, with a further distinction between single, widowed and divorced individuals (including married but living apart from their spouse).
- Living with others (excluding spouse) in private Las.
- Living in an institutional LA (mostly residential and nursing homes for the elderly).

For the current analysis, 3.14 million persons in the cohorts born before 1941 are observed from 1 January 1991 until 31 December 2010. The exact dates of occurrence of the demographic events of each individual are identified. In order to compute annual LA transition probabilities the LA is determined on 1 January of each year. Where LAs changed during the calendar year, the exact date of this change is identified as the date of the last registered event (marriage, divorce, widowhood, migration). Events that do not result in a change of LA compared with the previous year are not considered, e.g. subsequent moving out of and into the household, or a change in the place of residence of the whole household. In total, 1.68 million deaths are reported in the dataset and more than seven million LA episodes are defined within a delimited period of time when an individual occupies the same LA.

The relationship between LAs and mortality risk is examined by calculating age-specific probabilities of death for each sex and years of age for each LA. We use the STATA *Life Table* procedure (actuarial method) with outcome = 1 (death) or 0 (survival) for each LA episode, which could be left, right-left, or right truncated. The LA is treated as a nominal covariate, age as a continuous covariate (age 60 = 0), and sex as a binary covariate. The gender-specific single-year probabilities of death estimated from age 60 to 100 describe the mean mortality risk within each LA, averaged over the 20 years of observation.

In the second stage of the investigation we compute one-year transition probabilities between LAs as observed on 1 January and 31 December of a given year from 1991 to 2010. In light of these transition probabilities we apply the Multistate Life Table method to reconstruct synthetic LA trajectories for the largest group of individuals at age 60, e.g. the ever-married living with a spouse at age 60. These individuals might thereafter become widowed and live alone, and subsequently live with others in a private household or in an institutional household, and die in one of these four LAs. Their number represents 75% of the total population who reach age 60 and 84% of all ever-married individuals.

Results

The data displayed in Annex 1 indicate the proportion of the 3.14 million men and women included in this analysis in various LAs at selected ages between 60 and 90 years. The proportion of men living alone at their 60th

birthday is 13.8% and that of women is 17.9%. At age 80, the corresponding proportions are 21.1% and 48.0%. At age 60, 75.4% of men and 69.1% of women are living with a spouse. At age 80, 66.4% of men are still living with their wife but only 27.8% of women are living with their husband.

Probabilities of death according to living arrangement

The age-specific probabilities of death vary between the types of LAs. Overall they show an exponential increase with age. For each LA, the probability of death for men is about twice as high as for women, but the gender gap varies for different LAs and age groups. In absolute values the gender gap increases with age, but decreases in relative terms (see detailed figures in Annex 2). Parameter 'b' indicating the exponential increase of the rates adjusted with the Gompertz function varies among LAs. It is smaller for individuals living alone compared with those living with a spouse, with other persons, or in institutional LAs. This smaller 'b' value for those living alone could be combined with a higher intercept that reflects their greater mortality risk at age 60. The estimated probability of death at age 60 also differs by LAs – those living with a spouse exhibit lower values.

Figure 1 describes the single-year probabilities of death for individuals living with or without a spouse in private LAs. The former group also includes individuals with children or other persons in their household, and the latter group includes all individuals who do not live with a spouse, i.e. never-married, widowed, divorced, and also married persons who live apart from their spouse. The advantage of living with a spouse emerges in both genders but not over all ages. It is clearly favourable for both men and women to live with a spouse at relatively younger ages, but with increasing age the effect of this LA becomes weaker and finally disappears. The crossover in probabilities of death for those living with or without a spouse occurs at age 82 for women, but it appears only very slightly and at age 88 for men.

FIGURE 1 Age-specific probabilities of death (per 1'000, log scale): living with or without a spouse in private living arrangements (Belgium, 1991-2010)

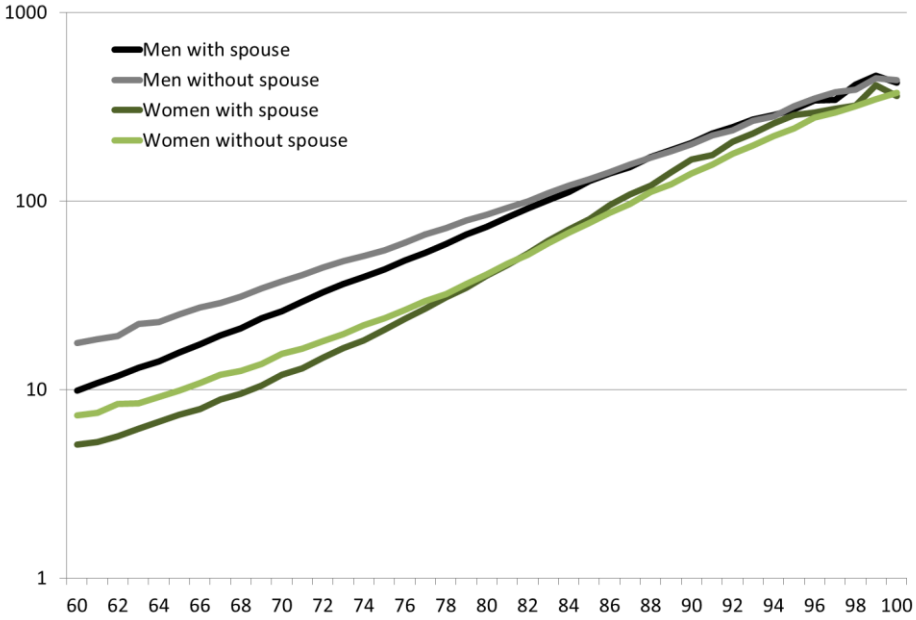


Figure 2 shows the probabilities of death for persons living with a spouse (children and others may also live with them) and for widowed persons living alone. Comparing the probabilities of death of persons who live with a spouse with those living alone as widows or widowers is important, as the latter is the most probable LA after the death of a spouse. Such a comparison could reveal the difference in mortality risk for persons who survive their spouse compared with those who still live with a spouse. As seen in Figure 2, living with a spouse is associated with a lower mortality risk at younger ages for both genders, but the probabilities of death converge and the difference disappears with increasing age. The difference between women living with a spouse and widows living alone disappears at age 75, and the relative survival advantage of widows at older ages is almost equal to their relative disadvantage at younger ages. Conversely, this mortality crossover appears only after age 85 for widowers, and their advantage compared with men living with their wife appears to decrease at older ages compared with the advantage for widowed women.

FIGURE 2 Age-specific probabilities of death (per 1'000, log scale): living with a spouse or widows and widowers living alone (Belgium, 1991-2010)

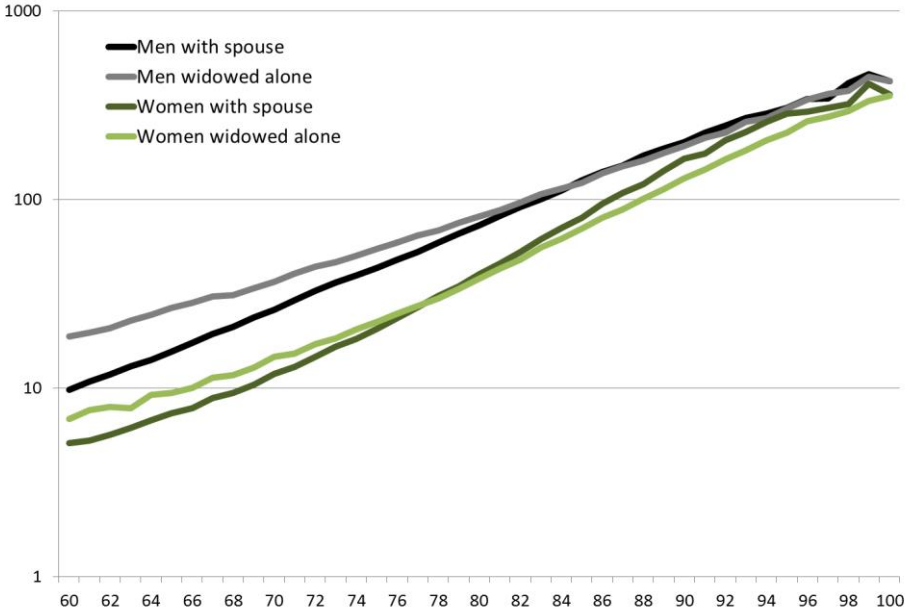
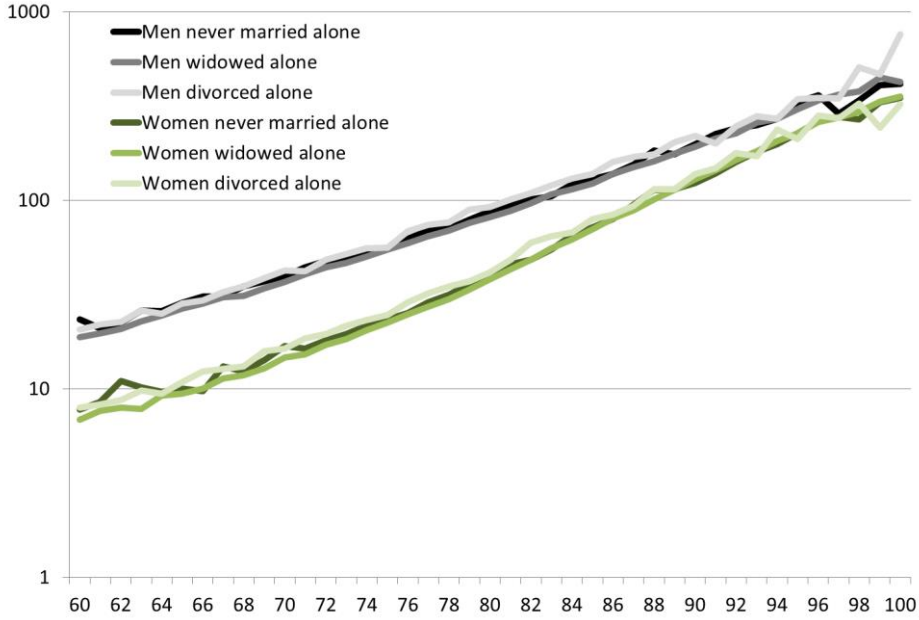


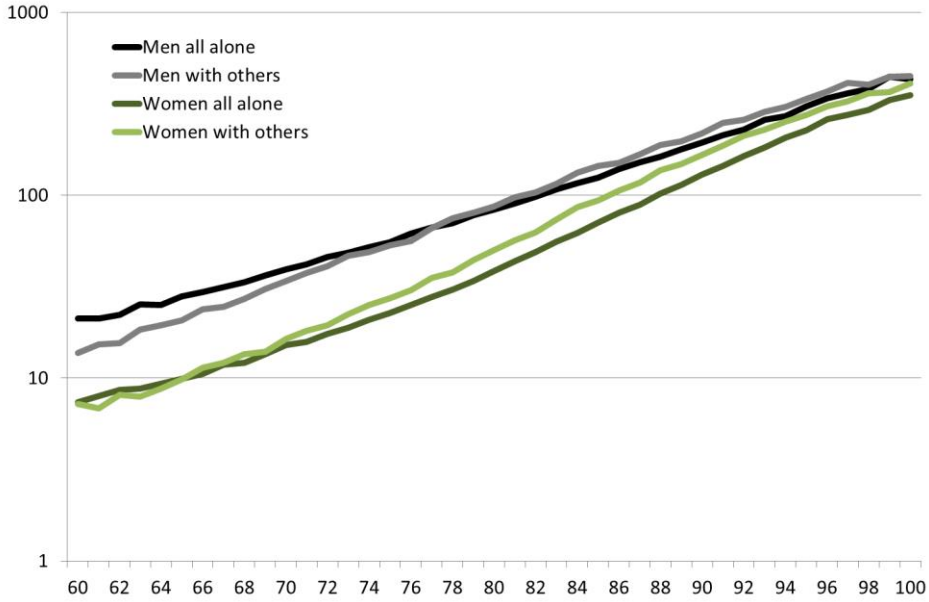
FIGURE 3 Age-specific probabilities of death (per 1'000, log scale): living alone (never-married, widowed or divorced) (Belgium 1991-2010)



Contrasting the age-specific probabilities of death for three categories of people living alone at older ages, i.e. never-married, widowed, or divorced, reveals very small differences (Figure 3). The probabilities of death for the never-married and widowed do not differ appreciably, but are slightly higher for divorced men and women, without a clear crossover.

A crossover appears in the probabilities of death for individuals living alone and for those living with others in private LAs (Figure 4). The mortality risk for men living alone or living with others becomes equal at age 78, and living alone is relatively more favourable after that age. Women living alone or living with others have the same probability of death at the age 60 baseline, but it diverges at about age 70, and living alone is associated with lower probabilities of death at older ages.

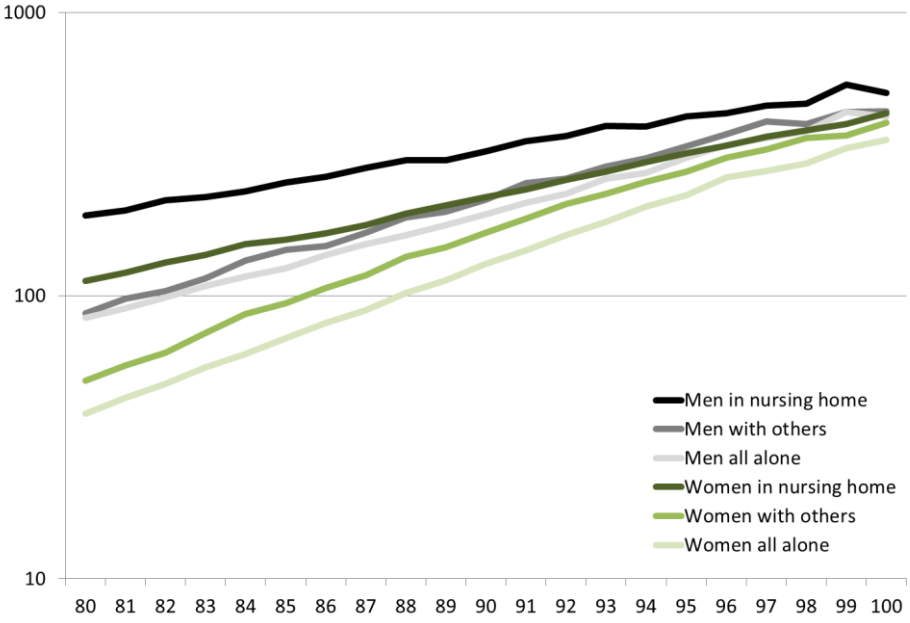
FIGURE 4 Age-specific probabilities of death: living alone or with others (excluding spouse)



After the loss of a spouse widowers and widows might live alone, live with others, often with one of their children, or enter a nursing home. Figure 5 exhibits the probabilities of death for these three groups starting from age 80. Compared with persons living alone or with others in private LAs the mortality risk is remarkably higher in institutional LAs. The excess mortality in institutional LAs decreases in relative terms at the oldest ages but the absolute difference is stable.

The gender gap in the mortality risks by age in private LAs is similar to the one in institutional LAs and decreases with age for both LAs.

FIGURE 5 Age-specific probabilities of death over age 80 (per 1'000, log scale): living alone, living with others (excluding spouse) or living in institutional living arrangements

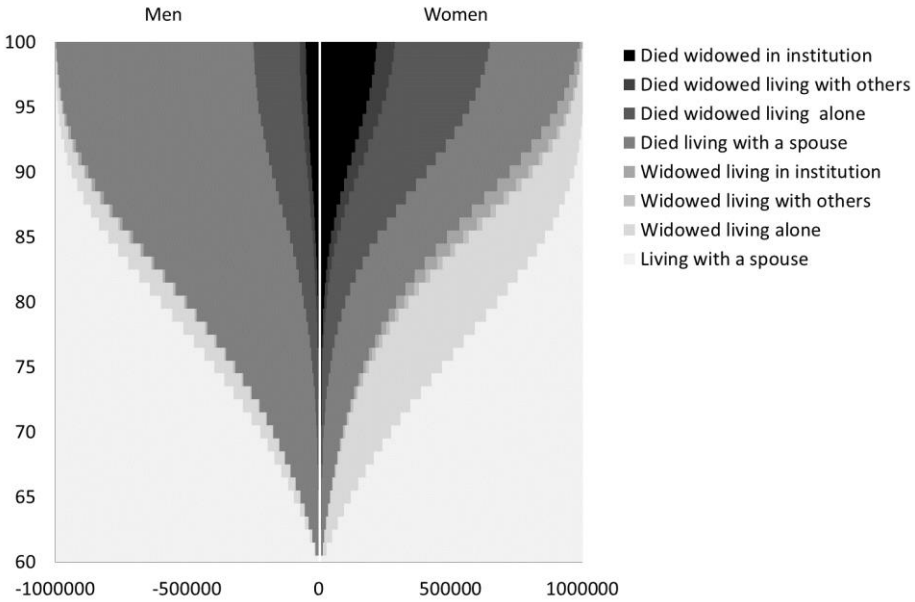


Mortality risk of persons living with a spouse at age 60, by their living arrangement trajectories

Among people aged 60 and over the largest group is still living with a spouse, but their proportion naturally decreases with age. For many people widowhood occurs after age 60, and the surviving spouse has to make a choice among future LAs. This might involve remaining alone or living with other persons, or in a nursing home. Considering that increasing age usually diminishes the ability to manage one's daily life, most old people are expected to change their LAs from living alone to living with others or to a nursing home. The multistate life table based on gender-specific annual LAs transition probabilities shows the relative quantitative evolution of the synthetic cohort of one million men and women living with a spouse at age 60 by LAs up to age 100 (Figure 6). The results displayed

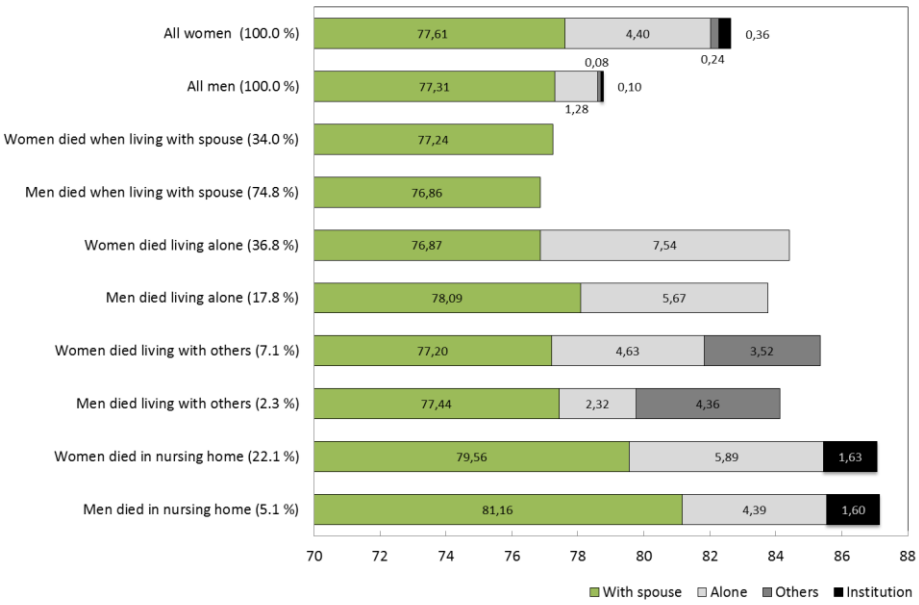
on Figure 6 represent men on the left and women on the right. Men living with their spouse are shown on the extreme left and women in similar LAs on the extreme right. The following three areas from both sides to the centre represent men and women having other LAs (living alone, with others and in institution) at each age. In the four areas closer to the centre are presented men and women who have died according to their last LAs.

FIGURE 6 Survival by living arrangement trajectories of the synthetic cohort of men (left) and women (right) living with a spouse at age 60 (Multistate life table for Belgium, 1991-2010)



The proportion of LA trajectories displayed in Figure 6 for persons living with a spouse at the baseline (age 60) exhibits large gender differences from age 60 to death or to age 100: the proportion of men who died while living with a spouse is twice as high compared with women (74.8% of men versus 34.0% of women). Conversely, twice as many women died as widows living alone (36.8% of women versus 17.8% of men), three times as many living with others (7.1% versus 2.3%), and four times as many in a nursing home (22.1% versus 5.1%).

FIGURE 7 Expected years of life for men and women who lived with a spouse at age 60 by various living arrangement trajectories (Multistate Life Table for Belgium 1991-2010)



This multistate life table allows one to estimate the expected years of life for persons living with a spouse at age 60 according to their LA trajectory (Figure 7). With no distinction for LAs, men and women living with a spouse at age 60 are expected to survive to age 79.8 and 82.6 respectively. As anticipated, men and women who died while living with a spouse had a shorter expected lifespan but with a largely reduced gender gap – 76.9 years for men and 77.2 for women. The expected lifespan of those who died as widows or widowers living alone was larger – 83.8 and 84.4 years respectively for men and women. When the expected lifespan was decomposed by time lived with a spouse and alone, men survived longer with a spouse than women (to age 78.1 compared with 76.9) but women lived longer alone than men (7.5 years compared with 5.7). Those who after living alone lived with others before they died had a slightly higher life expectancy than those who lived alone until their death – 84.1 years for men and 85.6 years for women. Among people who follow this LA trajectory, men spent half the time living alone and remained living with others for a significantly longer time before their death than did women (4.63 versus 2.32). Finally, life expectancy is longest for those who died in a nursing home after living alone; this is not surprising as attaining such an old age gives individuals more opportunity to enter a nursing

home. No difference was found in the life expectancy of men and women in this case – 87.1 years for both. Whereas both men and women spent about equal time in a nursing home, men who died in a nursing home spent more time from age 60 until their death living with a spouse and less time living alone than did women. It is remarkable that the relatively large gender gap found initially for men and women without distinguishing LAs cannot be the result of reduced advantages found for each LA trajectory but is rather because of the different proportion of men and women in different LA trajectories: three fourths of men but only one third of women died while living with a spouse.

Summary and discussion

The results of our study confirm that in addition to marital status, mortality risk in old age is also associated with LAs (H1) as earlier stated by Staehelin *et al.,* (2012) and Herm *et al*., (2015). Distinguishing by LA in addition to marital status discloses more variations in mortality risk especially between the never-married and widowed persons living alone, with others or in institutional LAs. The variation in mortality risk by LAs increases in absolute figures with age but decreases in relative terms at least up to age 80. Living with a spouse is favourable, and the protective role of marriage suggested by several researchers and identified by the review of the literature done by Rendall *et al.,* (2011), is confirmed by the results of our study. Nevertheless, the positive association between survival and living with a spouse tends to diminish with age. Living with a spouse at the oldest ages does not provide any more protection than at younger ages, a conclusion that is in line with the findings for the Swiss population by Staehelin *et al.,* (2012). The need to take care of a spouse whose health is deteriorating could become more prevalent at the oldest ages, which may affect the health of the caregiver. On the contrary, persons who live alone do not assume the role of caregiver and could avoid the possible negative effect. Compared with persons who live with others the survival of persons living alone is lower at relatively younger ages but becomes higher later in life. It is certainly a selection effect that allows the stronger individuals among those living alone to reach higher ages, while persons who are selected for surviving their spouse or others are also selected for the group of persons living alone in later life.

At all ages, living in institutional LAs is detrimental compared with private LAs, which confirms previous findings of excess mortality in nursing homes (Grundy, 2010). Entering a nursing home is most often linked to

health deterioration, yet the excess mortality in nursing homes remains even after the mortality risk is controlled by health status (Herm *et al.*, 2014). This clearly suggests a selection linked to health deterioration that is probably not sufficiently captured by health indicators. Among other reasons thought to be responsible for the excess mortality in nursing homes are a possible effect of the trauma of relocation to an unknown environment, and acute events that often follow admission to a nursing home (Raines, Wight, 2002). However, we find that at the oldest ages the negative association between living in institutional LAs and survival is reduced in both relative and absolute terms. That suggests that among relatively younger and older individuals a different selection mechanism is in operation for entering nursing homes.

The results of this analysis confirm that the association between LAs and mortality risk in old age varies by gender (H2). The absolute difference between the probabilities of death for both genders obviously increases with age as overall mortality increases, but the gender gap is reduced by a factor of two in relative terms. Hence, some LAs are relatively more beneficial for men whereas others favour women's survival. The greatest gender gap in probabilities of death appears among persons living alone, as also posited by Kandler *et al*., (2007). The gender gap is smaller for persons living with a spouse and in relative terms decreases more rapidly by age, a tendency also identified by Koskinen *et al.,* (2007). Because of health deterioration at the oldest ages, the choice of LAs becomes limited to living with others, usually with children if any, and living in a nursing home (Mutchler, Burr, 1991). We observed that men usually choose to live with others, whereas women reject this option and enter a nursing home, probably for psychological reasons. Above age 90, the mortality risk for men and women living with a spouse tends to converge. This finding offers additional proof that living with a spouse is relatively more protective for men than it is for women. A higher mortality risk emerges for women who are living with a spouse in their early 80s compared with women not living with a spouse, whereas for men such a situation is postponed to the oldest ages and is less accentuated. This result indicates that for men the favourable effects of living with a spouse persist longer than they do for women, and that no other situations are associated with a longer life. The reconstruction of LA trajectories from age 60 to 100 for a synthetic cohort provides new insight into the association between LAs and mortality risks, and its gender specificity. The longer survival of women compared with men could be explained by a larger proportion of women following LA trajectories that are associated with longer survival.

The age patterns of mortality risks for some pairs of LAs converge or diverge and even cross over at a certain age (H3). Such a crossover appears both for women and men living with or without a spouse, but with a reduced difference at the older ages. For men, living alone was unfavourable compared with living with others (spouse excluded) at relatively younger ages but became favourable later. Women did not experience a disadvantage from living alone compared with living with others at younger ages but the probabilities of death diverge later so that living alone became more beneficial, which fully supports the findings for the Swiss population (Staehelin *et al.,* 2012).

How might one explain the age and gender variation in the association between LAs and mortality risks? In relation to age variation, our investigations reveal that the lower the level of mortality risk at age 60, the greater its exponential increase at older ages. Such a negative correlation could be explained by a selectivity mechanism. Among those living alone – the group that exhibits the highest level of mortality at age 60 – the frailest are the first to die, which results in the probability of death increasing more slowly at later ages. Among people living with a spouse, the surviving spouse is typically selected for better health, which populates the group of widowed living alone with healthier individuals and those with the ability to manage living alone. Moreover, such a selection effect could narrow mortality differences by LAs in relative terms.

Why are mortality risks associated with various LAs and LA trajectories in old age? The two main factors determining the LAs of individuals in old age are past marital history and the deterioration of health with advancing age (Börsch-Supan *et al.,* 1996; Robards *et al*., 2013). Common reasons for older adults' changing LAs are widowhood and difficulty with continuing to live independently, the latter situation involving an increased need for care. If the person in need of care is living with a spouse, that spouse will usually be the primary caregiver (Chappell, 1991). Such support protects against premature mortality even when the health is relatively weak (Antonucci, Ajrouch, 2007), but it could have a negative effect on the health of the caregiving spouse, especially at the oldest ages (Navaie-Waliser *et al*., 2002). Widowed persons living alone may receive the needed support and care from their children or others living nearby. As long as they are relatively healthy, they may continue living alone without the burden of caring for someone else. However, when their own need for care increases, this may result in an unavoidable change of LAs from living alone to living with children or others. If no one can provide the needed care at home, the only option is institutionalization. These are the most frequent changes of LAs for older adults living with a spouse and

becoming widowed. For the never-married the change of LAs occurs earlier on average, as there is no spouse at home who could provide care in event that their health deteriorates. As many of the never-married do not have children (Festy, Rychtarikova, 2008), this change more often results in their entering a nursing home than it does for the ever-married. Never-married persons are institutionalized earlier and a greater proportion of them live in a nursing home compared with the ever-married. This situation supports the hypothesis that having a spouse plays a major role in preventing and delaying institutionalization (Nihtilä, Martikainen, 2008).

The gender gap in mortality risks by LAs is largely related to the general difference in life expectancy for men and women and in healthy life expectancy more specifically, as health is a key factor in the choice of LAs. An estimated gender gap of about four years in healthy life expectancy[4] has a direct consequence for the different timing of changes in LAs for men and women. This difference in life expectancy will potentially result in an earlier end of living alone for never-married men (due to death) compared with women. When one's health is deteriorating the possible choices are limited to living with others or living in an institutional LA. Both never-married men and women stay in these two LAs longer compared with the ever-married. For the latter, two other aspects – the age difference between spouses and the shock of widowhood – affect the gender differences in changes of LAs and their timing. A large age difference between spouses in favour of older men has been proven to be a factor associated with their longevity (Fox *et al.,* 1979; Foster *et al*., 1984; Klinger-Vartabedian, Wispe, 1989; Drefahl, 2010). Accordingly, husbands usually become dependent and require care before their wives. Conceptually, we may divide the life span of ever-married men and women in old age as follows:

- The first period, when both spouses are relatively healthy and benefit from being married due to psychological reasons and the positive aspects of mutual support.
- The second period, when the husband (more often) becomes dependent and his (still relatively healthy) wife takes care of him as primary caregiver, a situation that is favourable for the husband who receives needed care, but could be a rather difficult period for his wife.
- The third period, which follows the death of the spouse; the so-called shock of widowhood has been found to be stronger for men than for women, but its impact is relatively less pronounced with increasing

4. According to Eurostat, healthy life expectancy (HALE) in Belgium is 70 years for men and 74 for women.

age, as described by several authors (Thierry, 1999; Delbès, Gaymu, 2002; Guilbault *et al*., 2007; Roelfs *et al*., 2012). This conceptual framework may contribute to understanding why men and women adopt different LAs and face different mortality risks after age 60, and why more widows than widowers live alone and face a relatively lower mortality risk.

Our contribution provides an original perspective on the association between LAs and mortality, as few studies have considered the lifespan up to age 100 and used exhaustive data on an old-age population. Some limitations apply to this analysis although they do not affect the quality of the results. The use of data extracted from an administrative database could introduce some biases, and the availability of some variables, particularly those describing the socio-economic factors and health status of the oldest olds is limited. Pooling data over twenty years increases the statistical significance of the results but ignores the variation in the proportion of the elderly by LAs and the improvement in their chances of survival during that period. Analysing recent trends in LAs and associated mortality risks will be the subject of further work. In accordance with the suggestion of Bures (2009), deeper investigation needs to be made into how LAs affect the lives of individuals and their survival. In conclusion, not only marital status but also LAs are associated with mortality risks in old age. The choice of LAs is determined by health, the availability of a spouse and children, and socio-economic living conditions. As these factors are pertinent to social policies, this contribution aims to give concrete support to the debate on the future needs of the elderly within the context of population ageing.

Acknowledgements

This paper is published as part of the Local Population Projections project funded by the *Institut wallon de l'évaluation, de la prospective et de la statistique* (IWEPS) of Wallonia Region, Belgium. It has also benefited from the support of the Estonian Ministry of Education and Science, under Research Theme SF0130018s11, and ETF Grant No. 8904.

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Annex 1.
Proportion of individuals by LAs, 1991-2010

MEN

Age	Alone, never married	Alone, divorced or sepa-rated	Alone, wiowed	With spouse	Cohabit-ing	With others	In collective	Total
60	3.9	7.3	2.0	76.6	4.2	5.2	0.8	100.0
61	3.8	6.8	2.2	75.3	4.0	4.9	0.8	97.8
62	3.7	6.4	2.5	73.8	3.7	4.5	0.8	95.3
63	3.6	5.9	2.7	72.1	3.5	4.2	0.8	92.9
64	3.5	5.4	3.0	70.3	3.3	4.0	0.8	90.3
65	3.4	5.0	3.2	68.9	3.2	3.8	0.9	88.4
66	3.3	4.6	3.5	67.3	3.0	3.7	0.9	86.4
67	3.2	4.3	3.8	65.8	2.9	3.6	0.9	84.4
68	3.1	4.0	4.2	64.3	2.8	3.5	1.0	82.7
69	3.0	3.7	4.6	62.9	2.7	3.4	1.0	81.2
70	2.8	3.4	4.9	60.9	2.6	3.3	1.0	79.0
71	2.6	3.1	5.2	57.8	2.4	3.2	1.1	75.4
72	2.4	2.7	5.4	53.9	2.2	3.0	1.1	70.8
73	2.2	2.4	5.5	49.9	2.1	2.9	1.1	66.2
74	2.0	2.1	5.7	46.2	1.9	2.8	1.2	61.9
75	1.9	1.9	5.8	42.7	1.8	2.7	1.2	57.9
76	1.7	1.7	6.0	39.3	1.6	2.6	1.3	54.1
77	1.5	1.5	6.1	35.7	1.5	2.5	1.3	50.2
78	1.4	1.3	6.2	32.1	1.3	2.4	1.4	46.1
79	1.2	1.1	6.1	28.4	1.2	2.3	1.5	41.8
80	1.1	0.9	6.0	24.7	1.1	2.2	1.5	37.5
81	0.9	0.8	5.9	21.2	0.9	2.1	1.6	33.5
82	0.8	0.7	5.6	18.0	0.8	2.0	1.7	29.5
83	0.7	0.6	5.3	14.9	0.7	1.9	1.7	25.7
84	0.6	0.5	4.8	12.2	0.6	1.7	1.7	22.0
85	0.5	0.4	4.4	9.6	0.5	1.5	1.7	18.5
86	0.4	0.3	3.8	7.4	0.4	1.4	1.6	15.3
87	0.3	0.2	3.3	5.6	0.3	1.2	1.5	12.5
88	0.2	0.2	2.8	4.1	0.2	1.1	1.4	9.9
89	0.2	0.1	2.2	2.9	0.2	0.9	1.3	7.7
90	0.1	0.1	1.7	2.0	0.1	0.7	1.1	5.9
91	0.1	0.1	1.4	1.3	0.1	0.6	0.9	4.5
92	0.1	0.0	1.0	0.9	0.1	0.5	0.8	3.3
93	0.0	0.0	0.8	0.6	0.0	0.4	0.6	2.5
94	0.0	0.0	0.6	0.4	0.0	0.3	0.5	1.8
95	0.0	0.0	0.4	0.2	0.0	0.2	0.3	1.2
96	0.0	0.0	0.2	0.1	0.0	0.1	0.2	0.8
97	0.0	0.0	0.2	0.1	0.0	0.1	0.2	0.5
98	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.3
99	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.2
100+	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.2

WOMEN

Age	Alone, never maried	Alone, divorced or sepa-rated	Alone, widowed	With spouse	Cohabit-ing	With others	In collective	Total
60	2.5	7.5	7.4	70.0	3.4	8.4	0.8	100.0
61	2.4	7.2	8.4	68.4	3.3	8.2	0.9	98.8
62	2.4	6.8	9.4	66.6	3.2	8.1	1.0	97.4
63	2.5	6.3	10.5	64.6	3.0	8.0	1.0	96.0
64	2.5	5.9	11.7	62.5	2.9	8.0	1.1	94.6
65	2.5	5.6	13.1	60.8	2.9	8.0	1.2	94.0
66	2.5	5.3	14.5	58.9	2.8	8.1	1.3	93.3
67	2.6	5.0	16.1	56.9	2.7	8.3	1.4	92.9
68	2.6	4.7	17.7	54.9	2.7	8.5	1.5	92.7
69	2.7	4.5	19.5	53.1	2.7	8.7	1.7	92.8
70	2.7	4.3	21.3	50.7	2.6	8.9	1.8	92.3
71	2.7	3.9	22.6	47.3	2.5	9.0	2.0	90.0
72	2.6	3.6	23.5	43.4	2.4	9.0	2.2	86.6
73	2.6	3.3	24.3	39.5	2.2	8.9	2.4	83.2
74	2.5	3.0	25.1	35.8	2.1	8.9	2.7	80.0
75	2.4	2.7	25.9	32.3	2.0	8.9	3.0	77.2
76	2.4	2.5	26.6	29.0	1.9	9.0	3.4	74.7
77	2.3	2.3	27.1	25.7	1.7	9.0	3.8	72.0
78	2.2	2.1	27.2	22.4	1.6	9.0	4.3	68.8
79	2.1	1.9	26.8	19.2	1.5	8.8	4.8	65.2
80	2.0	1.6	26.1	16.2	1.3	8.7	5.3	61.3
81	1.9	1.4	25.1	13.5	1.2	8.5	5.8	57.3
82	1.7	1.2	23.7	11.0	1.1	8.2	6.3	53.2
83	1.6	1.1	22.0	8.7	0.9	7.8	6.8	48.9
84	1.4	0.9	20.0	6.8	0.8	7.4	7.1	44.4
85	1.2	0.8	17.8	5.1	0.7	6.8	7.3	39.7
86	1.1	0.6	15.4	3.8	0.6	6.2	7.3	35.0
87	0.9	0.5	13.0	2.7	0.5	5.6	7.2	30.3
88	0.7	0.4	10.7	1.8	0.4	4.9	6.8	25.8
89	0.6	0.3	8.6	1.2	0.3	4.2	6.3	21.5
90	0.5	0.2	6.7	0.8	0.2	3.6	5.6	17.6
91	0.4	0.2	5.1	0.5	0.2	3.0	5.0	14.3
92	0.3	0.1	3.9	0.3	0.1	2.4	4.3	11.5
93	0.2	0.1	2.9	0.2	0.1	1.9	3.6	9.0
94	0.2	0.1	2.1	0.1	0.1	1.5	2.9	6.8
95	0.1	0.0	1.4	0.1	0.0	1.1	2.2	5.0
96	0.1	0.0	0.9	0.0	0.0	0.8	1.6	3.5
97	0.1	0.0	0.6	0.0	0.0	0.5	1.2	2.4
98	0.0	0.0	0.4	0.0	0.0	0.4	0.8	1.6
99	0.0	0.0	0.2	0.0	0.0	0.2	0.5	1.0
100+	0.0	0.0	0.3	0.0	0.0	0.3	0.8	1.5

Annex 2.
Age-specific probabilities of death, by living arrangements, 1991-2010 (per 1'000)

MEN

Age	With spouse only	With spouse and child	With spouse and others	ALL with spouse	Alone never married	Alone widowed	Alone divorced	ALL alone	ALL with others	*CV* in private LA (%)*	In institu-tional LA (all types)	ALL LA
60	10.69	10.79	13.87	10.81	20.93	19.65	21.87	21.17	15.30	*43.8*	48.03	12.83
61	11.76	11.65	15.81	11.84	22.52	20.85	22.67	22.26	15.55	*40.9*	54.85	13.84
62	12.91	12.94	18.57	13.07	25.95	22.89	26.10	25.35	18.50	*44.6*	57.87	15.52
63	14.06	13.53	21.10	14.12	25.92	24.43	24.99	25.15	19.49	*36.6*	57.51	16.42
64	15.19	16.17	24.43	15.66	28.63	26.70	28.42	28.03	20.76	*37.6*	69.44	18.22
65	16.89	18.36	24.36	17.39	30.88	28.30	29.43	29.54	23.85	*33.2*	72.23	20.09
66	18.96	19.86	26.34	19.33	30.95	30.67	32.55	31.46	24.55	*30.1*	85.84	22.03
67	20.83	21.70	28.03	21.18	34.91	31.07	34.92	33.55	27.06	*29.0*	86.45	24.00
68	23.18	25.78	30.34	23.79	37.18	34.02	38.71	36.46	30.70	*26.6*	90.59	26.81
69	25.49	28.23	32.43	26.09	39.69	36.76	42.40	39.28	33.89	*25.2*	99.95	29.41
70	28.80	30.54	37.59	29.28	44.18	40.56	42.08	41.93	37.69	*22.0*	101.19	32.64
71	32.20	34.14	42.58	32.74	47.83	44.01	48.39	46.10	40.92	*21.5*	117.46	36.46
72	35.48	39.36	45.99	36.24	49.59	46.71	51.80	48.61	46.86	*17.5*	121.75	40.16
73	39.02	41.50	44.83	39.47	53.35	50.23	55.72	52.15	49.06	*17.1*	126.83	43.56
74	42.69	45.47	53.92	43.31	55.70	54.97	55.89	55.31	53.24	*13.7*	140.67	47.70
75	47.77	49.42	57.54	48.21	62.62	59.31	68.58	61.68	56.21	*17.1*	156.15	53.19
76	52.34	55.74	60.72	52.92	69.35	64.30	74.09	66.86	66.37	*16.0*	165.48	58.87
77	58.89	59.31	73.69	59.34	70.78	68.90	76.68	70.39	74.83	*13.1*	173.39	65.39
78	65.53	68.86	80.87	66.26	79.11	75.62	89.49	78.05	80.10	*13.8*	175.71	72.75
79	72.70	73.28	89.40	73.21	87.28	81.45	92.44	83.64	86.74	*12.0*	192.23	80.31
80	81.40	82.18	95.25	81.86	94.48	88.03	100.87	90.31	97.56	*10.2*	200.43	89.47
81	90.31	98.38	107.78	91.50	101.14	96.60	109.57	98.47	103.68	*8.4*	217.47	99.69
82	99.69	102.62	128.13	100.76	105.24	107.16	119.87	108.11	115.19	*11.8*	222.40	110.15
83	110.80	111.59	138.82	111.69	121.45	114.89	130.14	116.85	133.28	*10.8*	234.03	122.52
84	126.65	121.61	156.35	127.14	129.36	123.10	138.13	124.85	145.21	*11.3*	250.96	137.06
85	138.67	148.19	158.06	140.07	138.34	137.70	160.12	139.30	149.90	*8.0*	262.98	151.05
86	150.11	150.85	178.95	151.20	154.44	150.62	170.23	152.15	167.26	*8.7*	282.50	165.98
87	168.83	176.95	202.67	170.78	183.03	160.51	175.23	163.12	188.65	*9.4*	299.96	184.68
88	185.10	186.87	228.64	187.06	174.79	176.58	203.84	177.86	197.63	*12.0*	301.33	199.65
89	198.90	213.41	251.33	202.44	199.08	192.09	219.52	193.87	218.75	*11.7*	323.91	219.05
90	226.83	223.14	239.95	227.23	224.04	212.34	199.35	212.55	249.85	*6.8*	351.19	245.09
91	240.84	273.85	306.56	247.07	240.09	226.80	247.27	228.47	259.38	*13.0*	366.28	263.36
92	266.19	277.19	326.62	270.88	251.06	258.77	278.45	259.06	285.95	*11.1*	396.69	293.68
93	285.37	229.95	353.47	286.33	270.94	271.17	269.96	271.11	305.10	*15.1*	395.41	307.07
94	309.83	260.05	308.01	305.85	332.09	304.64	344.83	307.52	337.30	*10.3*	429.62	340.54
Slope**	0.102	0.100	0.096	0.102	0.079	0.080	0.081	0.078	0.093		0 .063	0.099
Inter-cept at age 60	10.416	11.110	14.620	10.610	19.983	18.397	20.256	19.643	14.727		54.840	12.301
Fit	1.000	0.997	0.998	1.000	0.998	0.999	0.998	0.999	0.999		0.995	1.000

WOMEN

Age	With spouse only	With spouse and child	With spouse and others	ALL WITH SPOUSE	Alone never married	Alone widowed	Alone divorced	ALL ALONE	ALL with OTHERS	*CV* in private LA (%)*	In institutional LA (all types)	ALL LA
60	5.17	5.20	8.02	5.25	8.52	7.67	8.25	8.00	6.85	*26.7*	20.85	6.06
61	5.60	5.58	8.40	5.67	10.97	7.96	8.71	8.64	8.08	*34.6*	22.75	6.67
62	6.13	5.90	9.73	6.18	10.16	7.82	9.77	8.74	7.94	*29.4*	21.51	7.04
63	6.61	7.01	9.42	6.76	9.68	9.24	9.42	9.35	8.77	*19.9*	24.03	7.72
64	7.09	8.09	10.02	7.34	10.01	9.46	10.80	9.88	9.83	*18.4*	29.50	8.44
65	7.70	8.33	9.96	7.86	9.69	10.00	12.32	10.51	11.37	*19.6*	29.42	9.15
66	8.62	9.32	13.95	8.86	13.19	11.38	12.79	11.90	12.13	*24.4*	29.67	10.27
67	9.24	9.84	14.74	9.46	12.32	11.76	13.15	12.09	13.53	*20.5*	38.75	11.05
68	10.17	11.34	15.66	10.46	14.20	12.83	15.81	13.48	13.96	*21.6*	41.86	12.21
69	11.69	12.94	15.39	11.94	16.90	14.66	16.38	15.15	16.46	*17.1*	44.80	14.00
70	12.75	13.57	17.35	12.97	16.39	15.25	18.58	15.81	18.21	*16.5*	50.22	15.21
71	14.39	15.87	20.68	14.72	18.09	17.11	19.57	17.50	19.49	*16.0*	58.29	17.15
72	16.38	17.55	21.09	16.63	19.53	18.43	21.66	18.88	22.34	*12.6*	64.80	19.27
73	17.75	20.32	25.77	18.23	21.69	20.50	23.09	20.86	25.14	*15.0*	69.61	21.48
74	20.20	22.28	30.58	20.70	23.39	22.46	24.64	22.74	27.30	*17.7*	79.17	24.17
75	23.26	25.04	30.03	23.63	25.28	24.86	28.83	25.22	30.31	*11.7*	86.34	27.43
76	26.33	29.04	36.73	26.90	28.81	27.36	32.05	27.81	35.40	*15.1*	91.54	31.15
77	30.09	32.85	43.37	30.78	31.58	29.95	35.08	30.41	38.00	*17.7*	96.02	34.79
78	34.03	36.21	49.12	34.77	35.95	33.61	37.31	34.01	44.27	*18.2*	106.39	39.87
79	39.40	39.53	58.10	40.16	38.31	38.19	41.35	38.37	50.13	*21.6*	112.79	45.63
80	44.62	50.78	65.02	45.97	45.76	43.15	48.54	43.62	56.81	*19.7*	120.79	52.33
81	51.79	54.61	67.90	52.79	48.50	48.23	59.46	48.79	62.75	*16.3*	130.60	59.51
82	60.28	57.95	83.21	61.43	54.99	55.51	64.62	55.89	73.72	*20.4*	139.17	68.94
83	68.84	72.19	94.05	70.75	65.39	61.88	67.37	62.35	86.30	*19.1*	151.99	79.12
84	77.18	83.84	110.61	80.25	72.09	70.39	79.78	70.88	93.85	*21.5*	157.75	88.90
85	91.08	92.63	128.91	94.78	79.57	79.91	83.86	80.04	106.52	*24.2*	166.05	101.00
86	102.92	107.25	148.90	108.48	94.68	88.41	93.74	89.03	117.79	*25.2*	177.94	113.35
87	117.17	108.70	147.20	120.90	113.49	101.07	114.57	102.39	137.13	*16.2*	194.65	130.34
88	138.08	126.70	166.20	142.24	114.56	113.40	114.17	113.51	148.36	*18.4*	208.03	144.95
89	160.61	149.48	187.34	165.49	124.11	129.91	137.52	129.75	167.04	*18.7*	222.42	163.70
90	165.66	184.27	200.38	175.28	139.38	144.53	147.51	144.25	186.73	*17.2*	236.52	180.87
91	197.10	217.08	226.40	206.94	159.15	163.76	178.19	163.85	210.88	*17.6*	256.16	204.16
92	207.81	222.86	260.31	227.58	180.31	182.84	170.84	182.31	228.86	*18.7*	273.91	224.41
93	246.94	212.56	275.00	257.68	198.39	206.06	237.41	206.30	252.16	*14.6*	295.83	249.54
94	291.29	353.98	274.86	285.00	225.77	226.67	211.38	226.19	274.46	*24.2*	318.15	272.80
Slope**	0.122	0.121	0.114	0.123	0.099	0.104	0.101	0.102	0.112		0.082	0.118
Inter-cept at age 60	4.13	4.44	6.45	4.19	6.73	5.88	6.92	6.20	6.14		21.68	5.09
Fit	0.997	0.998	0.996	0.997	0.992	0.995	0.996	0.995	0.999		0.994	0.998

* Coefficient of variation; ** Estimated value of Parameter 'b' in Compertz function.