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Healthiness of Survival and Quality of Death Among Oldest Old in China Using Fuzzy Sets

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Abstract

Objectives—To investigate healthiness of survival and quality of death among oldest-old Chinese.

Methods—Grade of Membership (GoM) method is applied to fulfill our goals using a nationwide longitudinal survey in China.

Results—GoM method generates six pure types/profiles for healthiness of survival and five profiles/types for quality of death. The authors combine these 11 profiles into 4 groups. On average, a Chinese oldest old from 1998 to 2000 had 48% probability of experiencing healthy survival, with 30% experiencing unhealthy survival, 11% having nonsuffering death, and 11% having suffering death. Similar memberships of dying with nonsuffering conditions are found across ages among the decedents. Men have a higher probability of being in healthy survival and nonsuffering death as compared to women. Marriage, high social connections, nonsmoking, and regular exercise are important contributors to healthy survival and quality of death.

Discussion—It is possible to live to ages 100 and beyond without much suffering.

Keywords

China; Grade of Membership; oldest old; healthiness of survival; quality of death; suffering before dying

Introduction

Health is a multidimensional concept that consists of physical, mental, and social dimensions. The classical methods (e.g., factor analysis, discriminant analysis, latent class analysis, or item response theory) for classifying individuals' health status are usually constrained within one or few subdimensions (Gold, Woodbury, & George, 1990), and it is difficult to aggregate massive information on numerous subdimensions to calculate

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summarized overall measures of health status at the population level or at the individual level. Thus, there is a need to develop an extensive set of indicators to capture the full spectrum of this concept. Analytic techniques to reduce dimensionality are thus required because it is difficult to simultaneously handle all indicators. A most recent approach is to generate a cumulative deficit index by adding numerous deficits from different dimensions of health to measure the condition (Dupre, Gu, Warner, & Zeng, 2009). However, the latent class approaches and cumulative deficit score approach both have inherent deficits in classification for individuals whose health conditions are complex and highly variable, with healthy and unhealthy elements coexisting (Manton, Woodbury, & Tolly, 1994). First, it is very unlikely in the real world that individuals occupy only one health state because the full extent of health ranges from well-being to death if health is measured multidimensionally (Manton et al., 1994; Ware, 1987). Second, many health traits in analyses might be relatively rare, and hence, the distribution functions tend to be “clumped” at the boundary with summary measures generated from such rare traits also tending to be heavily concentrated near the boundary and with long and thin tails (Manton, Gu, Huang, & Kovtun, 2004). Thus, it would be unwise to rely on those common latent statistical methods and models.

The Grade of Membership (GoM) approach overcomes the limitations in categorizing individuals' health status when many multidimensional factors are involved in the analyses and makes it possible to classify individuals into different categories with full use of information available. The GoM model was first introduced into research by Zadeh (1965) in the middle of 1960s and has been further developed by Woodbury and Manton and their colleagues since the late 1970s mainly at Duke University (see, for example, Manton et al., 1994; Woodbury, Clive, & Garson, 1978; Woodbury & Manton, 1982). The GoM method is a nonparametric and multivariate method based on the fuzzy theory for analyzing highly dimensional discrete response data. The GoM technique was originally used to identify medical conditions of the American older adult population (Woodbury & Manton, 1982) and has now been applied for analyzing depressive symptoms and personality disorders (Cassidy, Pieper, & Carroll, 2001; Nurnberg, Woodbury, & Bogenschutz, 1999; Szádóczy, Rózsa, Pattern, Arató, & Füredi, 2003), genetic health studies (Corder, Woodbury, Manton, & Field, 2001; Manton et al., 2004), twin studies (Ning et al., 2010), and other fields of medical subjects (e.g., Hughes, Fillenbaum, Woodbury, & Siegler, 1996; Woodbury & Fillenbaum, 1996). In China, several studies have used such a methodology in analyzing health conditions of the older adult population (Gu & Zeng, 2001, 2002; Jiang & Zhou, 1997).

Healthy longevity is an important topic, but we know little (Christensen & Vaupel, 1996; Zeng, Poston, Vlosky, & Gu, 2008). The answer to healthy longevity determines not only the quality of life for the older adults but also for all people in the society (Zeng et al., 2008). A central question in research on healthy longevity asks why some people live to old ages in relatively good health while others die relatively young and suffer from various chronic diseases (Gu, Sautter, Huang, & Zeng, 2011). Healthy longevity can be measured in terms of whether the mortality decline will be accompanied by a compression or an expansion of the period of disability and morbidity (Zeng et al., 2008). In our point of view, it is not sufficient to just investigate probabilities of dying at oldest-old ages without distinguishing the degree of suffering before dying. Indeed, most health scholars and practitioners now tend to agree that promoting healthy longevity is accomplished with an improved quality of death (Dupre et al., 2009; Patrick, Curtis, Engelberg, Nielsen, & McCown, 2003; Wong, 2000). The goals of healthy aging are to eliminate or reduce suffering before dying, shorten the time of suffering before dying, or have a good death (Patrick et al., 2003). It is less meaningful if one survives to advanced ages but experiences a long period of being bedridden or other kinds of severe suffering because it will bring much

pain and burden to the oldest old themselves, their families, and society. Therefore, it is important to investigate determinants of health status of survivors and the extent of suffering before dying. Health status before dying could provide a potentially important measure of the success or failure of aging. Those who have long lives and are vibrant until shortly before death may offer the best possible example of healthy aging. In the United States it is estimated that end-of-life care utilizes nearly one eighth of all health care expenditures and about one third of Medicare expenditures (Emanuel, 1996). With one exception, no studies have investigated the degree of peacefulness or quality of death among a population-based sample in China (Dupre et al., 2009).

Numerous studies have examined the associations between mortality/survival and socioeconomic and psychosocial factors at late ages (e.g., Giles, Glonek, Luszcz, & Andrews, 2005; Gu, Feng, & Sautter, 2008; Lynch, Kaplan, & Salonen, 1997; Preston & Taubman, 1994; Smith & Kington, 1997; Wen & Gu, 2011; Yao & Robert, 2008; Zeng, Gu, & Land, 2007). Most of them have found that higher socioeconomic status is associated with lower mortality and that people who have greater psychological resources are more likely to have better health and higher survivorship. Many studies have also examined factors associated with quality of death in Western nations (e.g., Ferrucci et al., 2003; Gruenewald & White, 2006; Patrick et al., 2003). Yet we have not found any studies integrating survival and quality of death and investigating factors associated with healthy longevity under such a context.

This study attempts to examine age and sex differentials in healthiness of survival and suffering before death among the oldest-old population using a more holistic approach to measure these two conditions based on a unique data set. The study also aims to investigate how major socioeconomic, psychosocial, and behavioral factors are associated with healthiness and survival and suffering before death. One innovative feature of this study is that we investigate not only the health status among those oldest old who survived and were reinterviewed in the follow-up survey but also the quality of death among those oldest-old interviewees who died before the second wave. To our knowledge, this is the first attempt using survey data with a large sample to address the issues of suffering before dying of the oldest old in the developing countries. This study does not intend to answer questions of mechanisms and causality related to determinants of healthiness of survival and suffering before dying. We present a descriptive analysis to depict the “de facto” variations in healthiness of survival and suffering before dying among the oldest old in China associated with social and health covariates.

Data Sources and Methods

Data Sources

Data used in this article are derived from the first two waves of the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The CLHLS, which began in 1998, is the first nationwide longitudinal survey focusing on the oldest old ever conducted in a developing country. In-home visits were conducted in randomly selected halves of the counties/cities in 22 out of the 31 provinces in China. The sampled 22 provinces covered about 85% of the total population in China in 2000. Among the 22 sampled provinces, 21 provinces are dominantly Han Chinese who normally have high accuracy in age reporting; one province is dominantly *Zhuang* ethnicity, who over the years have been culturally and residentially integrated with the Han (Zeng & Gu, 2008). The CLHLS aimed to interview all centenarians in the sampled counties/cities (about 631 counties/cities in the 1998 wave) with informed consent. Lists of centenarians are provided by the local residential committees in urban areas or the local village committees in rural areas. Age of each centenarian was validated from various sources as available, including birth certificate, genealogical documents, household booklet,

and ages of their children and siblings (Zeng & Gu, 2008). For each centenarian interviewed, one nearby octogenarian and one nearby nonagenarian with predesignated age and sex were randomly chosen to be interviewed based on a random code assigned to the centenarian. If the random code assigned to a centenarian was an even number, a female octogenarian and a female nonagenarian were interviewed (odd numbers indicated male respondents). The ages of both the octogenarian and nonagenarian respondents were predesignated to match the last digit of the random code of the centenarian. If there were no appropriate octogenarians or nonagenarians available in the village or street of the sampled centenarian, the CLHLS team recruited respondents nearby. The term “nearby” refers to the same village or street, or the same town, county or city, when applicable. This sampling strategy is designed to ensure comparable numbers of randomly selected male and female octogenarians and nonagenarians at each age from 80 to 99. The CLHLS is very representative of the older adult population in the Mainland China; distributions of key variables are close to those in other nation-wide surveys. The CLHLS data set contains a weight variable reflecting the sampling design and ensuring the weighted sample distributions to match those in the population in the 22 sampled provinces in terms of age, sex, and urban-rural residence. In the baseline wave in 1998, interviews were conducted with 8,805 voluntary participants aged 80 to 105 with 2,264 centenarians, 3,013 nonagenarians, and 3,528 octogenarians. In the second wave in 2000, out of 8,805 original interviewees, 4,691 (53.3%) were surviving with 3,264 (37.1%) dead and 850 (9.6%) lost to follow-up. This is the first nation-wide longitudinal survey research project on oldest old aged 80 or older conducted in a developing country. A detailed description about the sampling design and data quality assessment of the CLHLS can be found elsewhere (Gu & Dupre, 2008; Zeng et al., 2001) and, thus, is not repeated here.

Variables

Extensive questionnaire data (more than 180 items) were collected from interviewees in the 1998 and 2000 surveys. The data include 65 variables measuring various dimensions of health status, such as ADL (activities of daily living: eating, dressing, bathing, toileting, transfer, continence); physical performance (upper extremities, picking up a book from the floor, standing up from chair, turning around 360 degrees); Mini-Mental State Examination (MMSE) to measure cognitive function (orientation, registration, attention and calculation, recall, language and capacity in understanding and self-coordination); various chronic diseases and their adverse impacts on daily life; visual, hearing, and other kinds of impairments, and so on. These variables are similar to those in studies of the U.S older adult population using the GoM method (e.g., Manton & Land, 2000). Some selected variables are presented in Table 1.

Comprehensive information about health status, disability, length of being bedridden, and suffering before dying were obtained for 3,264 oldest old who were interviewed in 1998 but died before the 2000 survey by interviewing a next-of-kin or a caregiver of these deceased interviewees.¹ Information before dying consists of 35 variables, such as causes of death, chronic diseases, ADL (activities of daily living) disability before dying, number of times the respondents were hospitalized or bedridden from last interview to death, whether the respondent was bedridden before death, whether she or he could get adequate medical

¹We have to rely on proxy report for deceased persons because most Chinese older adults do not have detailed and reliable medical records. Prior studies showed that proxy report for surviving older adults had minor bias (e.g., Magaziner, Spear, Hebel, & Gruber-Baldini, 1996; Parker, Thorslund, Lundberg, & Kareholt, 1996). One of the causes of biases in proxy report for surviving older adults is that the proxy may worry about the possibility of upsetting the older adult if he or she reports the older adult's severe disability or certain types of diseases (e.g., cancer). There is usually no such worry in proxy report for the deceased older adults. Although there are no studies on the proxy bias for deceased interviewees, we expect that the bias of proxy report for deceased older adults exists, but it may not be larger than the bias of proxy report for surviving older adults.

treatment when suffering disease, and so on. If the respondent required help with any of the ADL activities, then an additional follow-up question was used to measure how long the disability persisted (or partial disability). If the older adult was bedridden, another question was used that asked for how many days did the older adult remain bedridden. Data on the number of days before death the older adult did not go outdoors and the number of days before death the older adult spent more time in bed instead of staying out of bed were collected. These indicators are similar to the basic dimensions underlying the quality of death in late life (Dupre et al., 2009; Patrick et al., 2003). Some selected variables are presented in Table 2.

The CLHLS also collected data on demographic characteristics, economic resources, psychological characteristics, health practices, and so on. Following the literature, we included some major covariates from each of these dimensions (Wen & Gu, 2011; Zeng et al., 2007). These variables include age, sex, urban/rural residence, ethnicity (Han vs. non-Han), education (1+ years of schooling vs. none), economic independence (yes vs. no), marital status (currently married vs. not), living arrangement (living alone vs. with others), current smoking (yes vs. no), current heavy alcohol drinking (yes vs. no), regular exercise (yes vs. no), and optimism (yes vs. no). Details of the categorization of these analytical variables are discussed later when we examine their associations with healthiness of survival and suffering death in multivariate models.

Method

The GoM Model

Because numerous technical explanations of the GoM model can be found elsewhere (Berkman, Singer, & Manton, 1989; Gold et al., 1990; Manton & Land, 2000; Manton, Stallard, & Corder, 1998; Manton et al., 1994), only a brief introduction is provided here. The GoM model was developed to analyze multidimensional data in terms of fuzzy states for I individuals with a set of J categorical variables that have L_j distinct outcomes or response levels (Manton & Land, 2000). The total number of response levels for J variables is J^*L_j , which is classified into a set of dummy variables in the GoM model. In other words, each response level (x_{ij}) of a variable (j) is denoted by y_{ijl} , where $y_{ijl} = 1$ if $x_{ij} = l$ (l refers to a specific response of variable j) and 0 otherwise. K latent profiles or states (known as “pure types” in GoM terminology) of traits are identified in the GoM model.

This procedure is similar to conventional latent class analyses, although the latent classes are determined by a set of variables that are either dichotomous or continuous. However, the GoM model has a unique way of using the structure of the data to construct dimensions or states as “pure types” or “profiles.” Two different parameters are estimated in the GoM model to define the characteristics of pure types and the probability (or degree) of each individual belonging to a given pure type. The first, λ_{kjl} , is the GoM structural probability,

which is subject to the constraints of $0 \leq \lambda_{kjl} \leq 1$ and $\sum_{l=1}^{L_j} \lambda_{kjl} = 1$. λ_{kjl} is the probability that the l th response ($l = 1, 2, 3, \dots, L_j$) of variable j th ($j = 1, 2, 3, \dots, J$; that is, x_{ij}) is observed for pure-type k ($k = 1, 2, 3, \dots, K$). In other words, λ_{kjl} is the probability of choosing response l of variable x_{ij} for a person completely from pure-type k (not from other pure types, see g_{ik} below for more details), where $\lambda_{kjl} = 1$ indicates that a person who is wholly from pure-type k will 100% choose the l th response for a given variable x_{ij} ; $\lambda_{kjl} = 0$ indicates that a person who is completely from pure-type k will definitely *not* choose the l th response for variable x_{ij} . In this regard, the main feature of a pure type is defined by λ_{kjl} (Manton et al., 1994; Ning et al., 2010; Stallard, 2007).

The other one is g_{ik} , the GoM score, which represents the probability of individual i being in pure-type k or the degree to which individual i is a member of pure-type k . g_{ik} s are convexly

constrained scores for individuals, that is, $0 \leq g_{ik} \leq 1$ and $\sum_{k=1}^K g_{ik} = 1$. $g_{ik} = 0$ indicates a zero membership; that is, individual i does *not* belong to pure-type k ; an individual with $g_{ik} = 1$ (complete membership) is exactly like the k th pure type or *completely* belongs to pure-type k , and it means partial membership when $0 < g_{ik} < 1$; that is, individual has *some but not all* characteristics of a single pure type. When an individual has a complete membership of a pure type, he or she wholly belongs to that pure type only and cannot belong to other pure types, which is the same as in the conventional classifications or other latent class analyses. However, for an individual whose g_{ik} is not equal to 1, he or she belongs to several pure types simultaneously with different probabilities or degrees. This is entirely different from conventional classifications and traditional latent class analyses. The membership of multiple pure types better reflects the reality (Manton et al., 1994).

Mathematically, the probability of $y_{ijl} = 1$ is defined by the following formula,

$$p_{ijl} = \text{Prob}(y_{ijl} = 1) = \sum_{k=1}^K g_{ik} \lambda_{kjl}, \text{ where, } \sum_{k=1}^K g_{ik} = 1, \sum_{l=1}^{L_j} \lambda_{kjl} = 1$$

For a given set of observations, the likelihood, L , is expressed as the product over i, j , and l of the set $\{y_{ijl} = 1\}$

$$L = \prod_{i=1}^N \prod_{j=1}^J \prod_{l=1}^{L_j} \left(\sum_{k=1}^K g_{ik} \lambda_{kjl} \right)^{y_{ijl}}, \text{ or}$$

$$\ln L = \sum_{i=1}^N \sum_{j=1}^J \sum_{l=1}^{L_j} y_{ijl} \ln \left(\sum_{k=1}^K g_{ik} \lambda_{kjl} \right),$$

$$\text{where, } \sum_{k=1}^K g_{ik} = 1, \sum_{l=1}^{L_j} \lambda_{kjl} = 1$$

λ_{kjl} s and g_{ik} s in the equation can be estimated by maximum likelihood following the procedure developed by Woodbury et al. (Woodbury, Mawnton, & Tolley, 1994). The number of dimension (K) is determined by comparing the Akaike Information Criterion (AIC) for models with different K s, with the lowest value of the AIC designating the best model (Corder et al., 2001; Gu & Zeng, 2001; Manton et al., 1994; Ning et al., 2010).

Variables used in the GoM model can be classified into two types: internal and external. Internal variables are used to define pure types, whereas external variables are used to address their relationships with the pure types. λ_{kjl} for each internal variable can be compared to the corresponding marginal frequency (observed frequency of each response in the overall sample) to determine the attributes associated with each type (Gu & Zeng, 2001; Manton et al., 1994; Ning et al., 2010). In the field of health studies, health measures are usually used as internal variables, whereas demographics and socioeconomic status are used as external variables (Manton et al., 1994).

The advantages of the GoM model over classical latent class analyses can be summarized as follows. First, latent class methods require that individuals belong to one and only one category. In contrast, the GoM model allows individuals to hold a complete membership in a

single category or a partial membership in multiple categories (Manton et al., 1994). Second, in the latent class models, as the number of variables in the analysis increases, the posterior probabilities of an individual being in a correct class tend toward 1 or 0 for all other classes, whereas in the GoM model, when more variables are used in the analysis, the GoM scores are better estimated without convergence to the boundary values, 0 or 1 (Stallard, 2007). Therefore, the multidimensionality and continuity of health can be well embodied. Third, the GoM model has its ability to identify latent profiles of health status using information on health indicators from all dimensions embedded in different variables, and it generalizes the traditional discrete classification and treats outcome scores as continuous variables based on the “fuzzy set” paradigm. This is impossible for conventional latent variable analyses. Thus, it is a superior alternative to the conventional classification methodologies used to capture the complex nature of health in its full extent (Manton et al., 1994; Ning et al., 2010; Stallard, 2007).

There are several options in GoM analyses to handle longitudinal or non-independent data (Gold et al., 1990; Ning et al., 2010; Portrait, Lindeboom, & Deeg, 1999). One is to analyze each longitudinal data set separately by wave and compare the typological results. The second is to combine two or more waves of data sets with no indication of which respondents are related. The third is the same as the second except adding an additional internal variable to indicate which respondents are related. Finally, a Lambda regression can be used to assume that in the later waves the respondents have the same structure of probabilities as in a previous wave. The first approach normally produces a different set of “pure types” for each wave and the probabilities of responses (λ_{kjl}) will be different, which makes it less comparable between waves. The second approach simply overlooks intrasubject dependence among observations of a same respondent. The third approach is only workable in theory or for small samples. This is because every variable in the GoM model (either the indicator variable, external variables, or internal variables) must be categorical with less than 20 categories in the current version of the DSIGOM package that we used in this study. In this regard, the third approach has its limitation. This is also one of major reasons why most previous studies using the GoM model did not adjust for dependence among observations. On the other hand, Lambda regression assumes a fixed λ_{kjl} for each respondent across waves, which might be a practical approach in the GoM model for better addressing intrasubject dependence in longitudinal data sets (Ning et al., 2010; Portrait et al., 1999).

This study used the DSIGOM beta version developed by Gene Lowrimore at Duke University and distributed by Decision Systems, Inc.

Multivariate Analyses

The GoM scores can be used as either outcomes or predictors in other models (e.g., Portrait et al., 1999; Seplaki, Smith, & Singer, 2004). Following the literature, we treat the GoM score as a set of outcomes reflecting healthiness of survival and quality of death under multivariate analysis of covariance (MANCOVA) after we combine pure types for survivors and pure types for the decedents. Five sequential models are constructed to investigate how demographic, socioeconomic, and psychosocial factors are related to healthiness of survival and quality of death. Model 1 controls for age, sex (male vs. female), urban-rural residence, and ethnicity (Han vs. non-Han). Model 2 further controls for social economic conditions measured by years of schooling (0 vs. 1+ years) and economic independence (daily expense is from pension/retirement wage or own work vs. from other sources). Model 3 additionally controls for psychosocial factors and health practice. The psychosocial factors are measured by current marital status (married vs. unmarried), living alone (yes vs. no), social connection (high vs. low), and optimism (yes vs. no). Social connection is considered high if the sampled person is frequently involved in playing mahjong and participating in religious

activities. The lifestyle factors are measured by current smoking (yes vs. no), current heavy alcohol drinking (yes vs. no), and doing regular exercise. Heavy alcohol consumption was defined as taking 200 grams liquor, 400 grams beer, or 300 grams wine or other alcoholic liquid daily. Model 4 adds the GoM score in 1998 (baseline health) into Model 1. The purpose of this model is to investigate how the associations between basic demographics and healthiness of survival and quality of death are affected by baseline health. Model 5 adds baseline health into Model 3. This model examines how each of the aforementioned factors is associated with healthiness of survival and quality of death in the presence of all other factors.

Findings

GoM Score for Healthiness of Survival

According to analytical distribution of the parameter λ_{kij} on variables measuring various health dimensions of the survivors, we find that the six profiles represent statuses of healthy, relatively healthy, moderately cognitively impaired, severely cognitively impaired, fully ADL dependent with diseases, and extremely frail, respectively (see Table 1). The “healthy” pure type (S1) means full independence in ADL, complete limb function, no disability, almost no chronic disease, and completely good cognitive function. The “relatively healthy” pure type (S2) means full independence in ADL, partially functioning limbs, almost no chronic disease, and in relatively good cognitive function. The “moderately cognitively impaired” pure type (S3) indicates almost full independence in ADL, highly limited functioning of low limbs, hearing impaired, almost no suffering from disease, and moderately impaired cognitive function. The “severely cognitively impaired” pure type (S4) indicates high independence in ADL, partial functioning of low limbs, suffering from some chronic diseases, impairment in hearing and visual function, and severely impaired cognitive function. The “fully ADL dependent with diseases” pure type (S5) represents full dependence in ADL and partial or no functioning of limbs, suffering from some diseases, especially heart attack, CVD (cardiovascular disease), and cancer, with vision impairment, but relatively good cognitive function. The “extremely frail” pure type (S6) means full dependence in ADL, poor functioning of limbs, partial or complete hearing and visual impairment, suffering from one or more chronic diseases, and severe impairment in cognitive function.²

The healthiness of survival is determined by GoM scores in the second wave, which are calculated by applying Lambda regression in 1998 to the 2000 data for those survivors. The results indicate (not shown) that 954 survivors had a score of zero (no membership) in the healthy profile (S1) in 2000. They account for 20% of the survivors. On the other hand, 339 oldest-old persons had a complete membership in the healthy profile (i.e., their score in the healthy profile is 1.0) in 2000, accounting for 7% of the survivors. Other survivors had a partial membership in the healthy profile in 2000. Almost no survivors had a complete membership in any of remaining five profiles.

The detailed distributions of the GoM scores of the healthy pure type for the survivors in 2000 against GoM scores in different pure types in 1998 are presented in Figure 1. The results show a heterogeneous feature in health dynamics among the Chinese oldest old.

For better description, we grouped the GoM scores in 1998 and 2000 for those followed-up survivors in 2000 and the results are presented in the left panel of Table 3. In order to more closely reflect the distribution of older adults in the population sampled, the GoM scores are

²Notice that the variables measuring cognitive function made a greater contribution to generating the six GoM (Grade of Membership) profiles than other variables did, which indicates that cognitive function is more important than other health variables.

weighted ex post to reflect the whole picture of the entire older adult population as suggested by previous studies (Manton et al., 1994, p. 36). The GoM scores listed in the left panel of Table 3 can be viewed as the probabilities of the membership of being in one of six pure types in 2000 for given probabilities in 1998 for a Chinese oldest old on average if she or he survived to the 2000 survey. The left panel of Table 3 shows that those who were healthier in 1998 would have a lower probability of being in healthy pure type (S1) in 2000 than their non-healthy counterparts. Similarly, those who had a lower probability of being in the healthy pure type in 1998 would have greater probabilities of being in other pure types in 2000. The left panel of Table 3 further indicates that dynamic changes in the GoM score across pure types from 1998 to 2000 are very common with a high probability of being in the healthy type. This indicates that on average the onsets of diseases or disability are not uncommon among the Chinese oldest old and recoveries from diseases and disability are even more common. Furthermore, a noteworthy pattern is that those who had a higher probability (gi2 = 50%) in the relatively healthy pure type (S2) and in the extremely frail type (S6) at baseline would have higher probabilities of 22% and 36%, respectively, in the MMSE severely impaired type (S4) 2 years later. Finally, a less significant but noticeable finding is the state dependence or state stability feature; that is, people who had a higher probability in a given type at baseline would have a relatively higher membership of being in the same type in the follow-up wave.

In an effort to investigate the gender and age patterns on changes in health status, we follow the approach of the GoM analysis used by Manton and Land (2000) and take those survivors who had a GoM score of 1.0 in the healthy profile (i.e., completely healthy) in 1998 to explore age pattern and gender differentials of the health status deterioration during the interwave period (1998–2000).³ Because of the problems of too small samples, we cannot investigate separately the respondents who had a GoM score of 1 in any one of the remaining five not-completely-healthy profiles in 1998. Alternatively, we choose those who had a GoM score of 0 in the healthy profile in 1998 to address their likelihood of returning to healthy status during the interwave period, while controlling for their GoM scores in the other five nonhealthy profiles in 1998.⁴ Differences in probabilities of healthiness of survival by age and sex are presented in Figure 2 adjusting for age distribution within the group, urban/rural residence, education, ethnicity, marital status, and living arrangement observed at the 1998 baseline survey. The results in Figure 2 clearly indicate that the probability of being in the healthy profile (S1) substantially decreases from 70% in men and 60% in women at ages 82 to 87 to 40% in men and 26% in women at ages 102 to 107 (Figure 2a). Yet the probability of being in the cognitively moderately and severely impaired combined profile (S3 and S4), for example, increases from 11% in men and 19% in women at ages 82 to 87 to 38% in men and 50% in women at ages 102 to 107 (Figure 2b). This age trajectory is persistent regardless of health conditions at baseline, although fully healthy oldest old have a higher probability of staying in the healthy type (Figure 2c) and nonmembers of the healthy type have a lower probability to being in the healthy type (Figure 2d). Women have a lower probability of being in the healthy profile and higher probability of being in unhealthy profiles than men regardless of age.

GoM Scores for Extent of Suffering Before Dying

We applied the GoM model to summarize the massive multidimensional information related to health status before dying or quality of death among deceased interviewees. We used 35 variables related to conditions of disability and suffering status before dying as internal variables in the GoM model. Five pure types fit the data best: nonsuffering, slight suffering,

³The interviewees with “complete healthy status” constitute 7% of the total sample of the 1998 baseline survey.

⁴We took GoM scores in other five nonhealthy profiles in 1998 as covariates.

moderate suffering, medium-term severe suffering, and long-term severe suffering. Each pure type is named by its main characteristics (see Table 2). The “non-suffering” pure type (D1) refers to full independence in daily life, no obvious disease as a cause of death, and almost no suffering from diseases before dying. The “slight suffering” pure type (D2) refers to slight suffering from disease, and almost no loss in ADL functioning. The “moderate suffering” pure type (D3) means full ADL dependence with heart disease. The “medium-term severe suffering” pure type (D4) means full ADL dependence, suffering from ADL full dependence for less than 1 year, being bedridden for less than half a year, and with one or two chronic diseases. The “long-term severe suffering” pure type (D5) indicates full ADL dependence, suffering from full ADL dependence for more than 1 year, or being bedridden for more than half a year, and with more than two chronic diseases, especially CVD and dementia.⁵

Our results indicate (not shown) that 1,201 dead interviewees had a zero membership of nonsuffering pure type (D1; their score in nonsuffering profile is 0), accounting for 37% of all deceased interviewees. In contrast, 926 deceased interviewees had a full membership in the nonsuffering death (their score in the nonsuffering profile is 1.0), accounting for 28% of all deceased interviewees. The others are partially nonsuffering death and partially suffering death. The numbers of deceased subjects who had a complete membership in any other four suffering death profiles are small.⁶

Figure 3 presents the distributions of the GoM scores of nonsuffering death pure type for the respondents who died before the 2000 follow-up wave against GoM scores in different pure types in 1998. The distribution indicates a diverse but similar pattern in dying without suffering conditions among these deceased persons. The right panel of Table 3 summarizes the average of these distributions. Similarly, we applied the ex post weight to the GoM score to more closely reflect the distribution of older adults in the population sampled. These GoM scores in the right panel of Table 3 can be viewed as the probabilities of being in one of five types of quality of death for a Chinese oldest old on average if she or he died between the 1998 and 2000 waves of the CLHLS. The results show that on average a Chinese oldest old has a relatively large probability of dying without suffering conditions (D1). The results further reveal that among respondents who died between 1998 and 2000, those having a higher probability in the healthy pure type (S1) in 1998 would have a higher probability to die with nonsuffering conditions. Those having a higher probability in cognitive impairments (S3 and S4) and extremely frail types (S6) at baseline would have a higher probability of death with medium-term severe suffering conditions (D4).

Similar to what we did for healthiness of survival analyses, we analyze age and gender patterns for quality of death. Differences in probabilities of quality of death by age and sex are presented in Figure 4 adjusting for age distribution within the group, urban/rural residence, education, ethnicity, marital status, living arrangement, and social connection observed at the 1998 baseline survey. Figure 4 shows that, unlike the age pattern in healthy survival, the probability of being in the nonsuffering death type (D1) among the decedents is flat from 53% in men and 45% in women at ages 80 to 84 to 52% in men and 42% in women at ages 100 to 107 (Figure 4a). Taking baseline health into consideration, it was found that the age trajectory does not change, although healthier people at baseline tend to have a higher probability of dying in nonsuffering and less healthy oldest old tend to have a smaller probability to die in such a type (Figures 4c and 4d). The age trajectory in

⁵Variables related to ADL (activities of daily living) and length of time spent in partially and fully dependent statuses made a greater contribution to generating GoM profiles of suffering before dying than do other variables.

⁶Eighty-four, 188, 158, and 200 persons had a complete membership in the slight suffering profile, the moderate suffering profile, medium-term severe suffering profile, and long-term severe suffering profile, respectively.

probabilities of severe suffering types (medium-term and long-term combined; D4 and D5) is also flat (Figure 4b). This is an important finding, which suggests that centenarians could have similar chances of dying without much suffering conditions. Men have a greater probability of dying without suffering conditions than women do.

Factors Associated With Healthiness of Survival and Quality of Death

We further combined the six pure types of survival and five pure types of quality of death together into four pure types to fully examine the associations between study variables and healthiness of survival and quality of death while keeping analyses simple. The four pure types are the healthy survival (S1), nonhealthy survival (S2+S3+S4+S5+S6), nonsuffering death (D1), and suffering death (D2+D3+D4+D5). As we will discuss these associations in detail below under the multivariate context, we only describe the overall results here. On average, a Chinese oldest old in 1998 would have nearly 48% probability of being in healthy survival type in 2000, 30% chance to survive to 2000 but in the nonhealthy status, 11% chance to be in nonsuffering death type, and another 11% chance to die with suffering conditions.

Table 4 presents the MANCOVA results on associations between covariates and healthiness of survival and quality of death types. Model 1 reports that men have 4% greater chance of surviving and being in the healthy type, 9% smaller chance of being in the nonhealthy survival type, and 6% greater chance of dying with nonsuffering conditions as compared to women. One additional year of age is associated with a 2% decrease in the chance of surviving in the healthy status, 1% greater chance of dying in the suffering conditions, and 1% greater chance of dying in the nonsuffering conditions. Urban oldest old had 2% greater chance to survive in the healthy status as compared to rural oldest old. Non-Han minorities had 4% greater chance to survive in the nonhealthy status and 5% less chance to die with the suffering condition. In addition, controlling for socioeconomic conditions (Model 2), the advantage in survival in the healthy status in men and urban oldest old disappears, but men's advantages in dying in nonsuffering conditions still persist. Compared to the oldest old without any schooling, those receiving 1 year or more of schooling have 5% higher probability of surviving in the healthy status and 2% lower probability of dying in the suffering condition. Economic independence increases the probability of survival in the healthy type by 6% and decreases the probability of dying in the nonsuffering condition by 5%. These significant associations between socioeconomic conditions and healthiness of survival and quality of death are largely reduced and turn to insignificant when psychosocial factors and health practice are further controlled for in the analyses (Model 3).

Model 3 also shows that marriage could increase the probability of healthy survival by 6% and decrease the probability of nonsuffering death by 5% as compared to those currently unmarried oldest old. High social connection increases the chance of being in the healthy survival type by 7% and decreases the chance of being in the suffering death type by 4%. Doing regular exercise could increase the chance of being in the healthy survival type by 9% and decrease the chance of being in the suffering death type by 9% as compared to those who do not do regular exercise. Optimism increases the chance of being in the healthy survival type by 8% and the chance of being in the nonhealthy survival type by 3%. Regular exercise is also associated with a decrease in the chance of being in the nonsuffering death type by 3% and the chance of being in the suffering death type by 4%. Living alone increased the chance of being in the healthy survival type by 4% and decreased the chance of dying in suffering conditions by 6%. Current smoking reduces the chance of being in the healthy survival type by 2%, whereas heavy alcohol drinking increases the chance of being in the healthy survival type by 4% and decreases the chance of being in the nonhealthy survival type by 4%. Model 4 investigates how the associations between demographic factors and healthiness of survival and quality of death were mediated by baseline health.

The results in Model 4 suggest that controlling for baseline health removes men's advantages in healthy survival over women. Model 4 further reveals that compared to individuals fully from the extremely frail type, those fully from the healthy type and those fully from the full ADL dependent with fatal diseases type have 35% and 21% greater chances, respectively, of being in the healthy survival type given the same demographics 2 years later. Yet those fully from the moderately cognitively impaired type have 12% lower chance of being in the healthy survival type 2 years later as compared to those fully from the extremely frail type given the same demographics. A full membership from the first five pure types all increases the probability of the nonhealthy survival type 2 years later by 9% to 22% as compared to the extremely frail type. These five types except the third (the moderately cognitively impaired) have a lower probability of dying with suffering conditions 2 years later by 31% to 44%. The differences in probabilities of the nonsuffering death for six pure types are not significant except for in the case between the relatively healthy type and the extremely frail type.

Model 5 includes all study variables in the present study. In this model, oldest-old men have 3% lower probability of being in the healthy survival type and 9% lower probability of being in the nonhealthy survival type, whereas they have 9% higher probability to die with nonsuffering conditions and 3% higher probability to die in suffering conditions. Once baseline health is controlled for, the higher probability of being in the healthy survival type among individuals with better socioeconomic conditions disappears. Baseline health also largely reduces the probability of being in the healthy survival type for psychosocial factors. For example, the higher probability of being in the healthy survival type associated with high social connection is reduced from 7% in Model 3 to 4% in Model 5 and from 8% in Model 3 to insignificant in Model 5 for optimism. Most significant associations between psychosocial factors and health practice and suffering death also become insignificant when baseline health is taken into consideration. Associations between baseline health and healthiness of survival and quality death are almost unchanged when other covariates are present.

Discussion and conclusions

The uniqueness of this study lies in using interwave information of both survivors and deceased interviewees based on the grade of membership method, which makes it possible to address healthiness of survival and extent of suffering before dying based on the same data set. The major findings of this study can be summarized into the following several folds.

First and the foremost, although health conditions of the older adults tend to decline with advancing age and this has been widely documented in the literature (e.g., Manton & Land, 2000; Zeng et al., 2007), the extent of suffering before dying does not vary significantly with age. This is a novel and very important finding in terms of understanding healthy aging. This also suggests that it is possible to postpone health deterioration to older age and to compress periods of morbidity or disability before dying. If personal health maintenance and supplemental preventive interventions are well conducted, and if positive trends in reducing health risks and promoting health behaviors are obtained, the majority would reach their ninth decade in good health and then die after a relatively brief period of illness. It seems to us that healthy longevity is not impossible.

The evidence that probability of dying with nonsuffering conditions is about half at oldest-old ages and does not vary significantly with advance in age suggests that there is still plenty of room to compress the suffering period before dying for the oldest old. Human beings' life span is expanding, and everyone eventually faces death. So, it is indispensable to draw more

attention to studies on what factors may contribute to elimination or reduction in suffering before death at oldest-old ages. According to the “compression of morbidity” hypothesis (Fries, 1980), some older adults, instead of experiencing a more or less steadily increasing rate of disability and deaths starting at midlife, could live reasonably well until the last days of life, and the shape of the morbidity curve could become cliff like at the end of life. Our results support this argument and suggest that it is possible for some very old people that illness and disability could comprise a small portion of the last stage of life (Rowe & Kahn, 1998). One of the hypotheses is that the extremely old persons may have lower probability of suffering from serious disease due to selection (i.e., those who had serious disease may likely die before reaching extremely old ages), which may compensate with their suffering from poorer functional capacity due to biological aging. Further research is needed to investigate causal mechanisms about age impacts on suffering before dying at oldest-old ages.

The issues on extent of suffering before death or quality of death have received increasing attention in Western societies since the 1980s (Ferrucci et al., 2003; Gruenewald & White, 2006; Guralnik, LaCroix, Branch, Kasl, & Wallace, 1991; Lawton, Moss, & Glicksman, 1990; Patrick et al., 2003) and in China since the 2000s (Dupre et al., 2009; Gu, 2004). The U.S. National Long-Term Care Survey collected information on health, disability, and suffering before dying from those old adults who were interviewed in the 1999 and 2004 waves. Patterns of psychological suffering, ADL disablement, cognitive impairment, and quality of life prior to death have been portrayed. For instance, based on 200 community residents aged 65 and over, Lawton and colleagues found that 42% of the decedents maintained ADL function capacity until 1 month before death; 73% of the decedents had good mental alertness until 1 month before death. Guralnik and his colleagues (1991) also argued that although the prevalence rates of disease and disability increased with age, there was no a priori reason to believe that, within older populations, those dying at a younger age should have less disability prior to death than those dying at older ages. Our finding based on a unique large data set from China, a developing country, that the extent of suffering before dying does not vary significantly with age, is in line with what has been found in the developed countries.

Second, as compared to oldest-old men, oldest-old women have a lower chance of being in a healthy profile and a larger chance of staying in unhealthy statuses compared to men, which is in accordance with previous research (Manton & Land, 2000; Zeng et al., 2007). It is worth noting that the oldest-old women also have a higher probability of dying with suffering conditions. Palmore and Burchett (1997) found that the gender difference in disability in the final year of life was not significant, but several other studies (Guralnik et al., 1991; Lawton et al., 1990; Losonczy, White, & Brock, 1998; Seeman, 1992) found that old women had a worse health status than old men in the last days of life in terms of disability and cognitive function. Based on multidimensional measurements, this study indicates that female decedents had a lower probability of experiencing nonsuffering death and they suffered more before dying than did their male counterparts. Our study provides evidence to confirm that oldest-old women are not only disadvantaged in healthy survival but also suffer more before dying. Yet oldest-old women on average have a higher probability of surviving (regardless of health conditions) than male oldest old. We speculate that the gender paradox in healthiness of survival and quality of death is mainly due to gender differences in genetic or biological risks acquired through lifestyle-related behaviors, illness behaviors (e.g., immune system responses, hormones, disease patterns), health reporting behaviors, socioeconomic statuses, and health care utilization patterns (e.g., prevention and investment behaviors; see Dupre et al., 2009; Oksuzyan, Juel, Vaupel, & Christensen, 2008; Zhu & Gu, 2010). Moreover, research shows that men are more likely to die suddenly whereas women are more likely to have a more gradual progression of poor

health (Puts, Lips, & Deeg, 2005). Our multivariate model does suggest that oldest-old men's higher probability of being in the healthy survival type is diminished once socioeconomic conditions are adjusted. It is thus particularly important to give more attention to gender equality in health care, empowerment of women, and other supports for female oldest old.

Third, we find that socioeconomic conditions are important factors significantly associated with healthiness of survival and quality of death, which is consistent with previous findings (see Preston & Taubman, 1994; Zeng et al., 2007). Socioeconomic conditions affect mortality and health because higher socioeconomic status could increase social/family support, health behaviors, and more material resources (e.g., housing conditions and access to health care) that ensure psychological well-being and physical function (see Wen & Gu, 2011). This is true, at least to some extent, because the effects of education and economic independence on healthiness of survival and quality of death in our models disappear when psychosocial factors and health practice are controlled for.

We also find that marriage and high social connection are associated with high probability of being in the healthy survival type even after baseline health is taken into consideration, which agrees with previous findings (Giles et al., 2005; Gu et al., 2008; Williams & Umberson, 2004; Zhu & Gu, 2010). Studies have shown that married individuals are better off financially, receive more emotional and instrumental support, experience less stress and are encouraged to maintain healthier habits than unmarried counterparts, and that marital dissolution could cause psychological problems and affect individuals' health and survival (Williams & Umberson, 2004; Zhu & Gu, 2010). All of these lead to overall better health and lower mortality among married persons. Social integration has been shown to promote healthy behaviors (Uchino, 2004), psychological well-being (McAuley, 1993), and metabolism and immune function (Seeman & Crimmins, 2001), which enables oldest old to maintain good health. On the other hand, isolation may disconnect older adults from social support (LaVeist, Sellers, Brown, & Nickerson, 1997), which expedites the rate of aging and deregulates the immune mechanism, thus producing deleterious effects on health (Berkman & Glass, 2000; Gu et al., 2008). Our findings underline the importance of marriage and social connection in their linkages with healthy longevity.

Our results further show that healthy behavior such as doing regular exercise increases the probability of healthy survival and decreases the probability of dying with suffering condition, which underscores the important contribution of good lifestyles to healthy longevity. Studies have shown that regular exercise could ease the neural system, activate biochemical systems of the body, improve the capacity of muscle, and improve immune system function (Gu, 2007; Rolland et al., 2006). On the other hand, unhealthy behavior such as smoking reduces the probability of healthy survival. Smoking is a significant source of oxidative stress, which is potentially harmful to an individual's health (Tafaro et al., 2004). Clinical and epidemiological evidence has shown that smoking is positively associated with overall cancer incidence, cardiovascular disease, chronic obstructive pulmonary disease, disability, and total and cause-specific mortality in the older adult population (Bratzler, Oehlert, & Austelle, 2002; Hubert, Bloch, Oehlert, & Fries, 2002; Tafaro et al., 2004). Indeed, smoking has been considered a modifiable lifestyle factor that prevents individuals from reaching the "compression of morbidity" (Hubert et al., 2002). Continued efforts in strengthening of national programs and initiatives for smoking prevention and cessation are clearly needed to reduce the prevalence of smoking in China and smoking-related diseases and deaths (Gu et al., 2009). A number of studies demonstrate that optimism, a positive attitude and view to life, is associated with lower morbidity and mortality (e.g., Giltay, Geleijnse, Zitman, Hoekstra, & Schouten, 2004; Shirai et al., 2009). Our result is in accordance with such a finding. Although the underlying mechanism is

unclear, research has argued that most optimists have a better skill in seeking social support and coping with stresses and crises, which likely enhances their health or recovery process (Giltay et al., 2004). Previous studies have found a J- or U-shaped association between alcohol consumption and mortality (Halme et al., 2010; Rehm, Gutjahr, & Gmel, 2001; Sun et al., 2009). This is possibly because heavy drinking tends to increase the risk of sudden cardiac dysfunction or death and other cardiovascular outcomes, whereas regular light-to-moderate alcohol consumption may improve the circulation system that is linked to favorable cardiac outcomes and other health conditions (Rehm, Gerhard, Sempos, & Trevisan, 2003). We find that older adults who are heavy drinkers tend to be in a healthy status and are less likely to be in nonhealthy status, although those heavy drinkers do not have a higher probability to die regardless of health condition before dying. This is contradictory to most findings in the literature. But it is not unexplainable. Literature has indicated that the association between heavy alcohol consumption and mortality risk is likely weaker among the older adult population (e.g., Klatsky, Armstrong, & Friedman, 1992) and that older adults who are heavy drinkers seem to have a similar mortality risk compared to their never-drinking counterparts (e.g., Sun et al., 2009). We thus speculate that this result is possibly because of mortality selection that has dropped those heavy drinkers with a frail condition at earlier ages, leaving few relatively robust heavy drinkers being able to survive to oldest-old ages. It is also possible that we may mix the associations between quantitative levels of alcohol consumption, between types of drinking, and between current drinkers and ex-drinkers, which would be too complicated to address and beyond the scope of the present study. We welcome more specific studies to better explore these associations.

It is obviously very difficult to summarize so many variables simultaneously to measure the healthiness of survival and extent of suffering before dying, based on the classic approach of computing average values of the cross-variables measurements, including information from dozens of indicators. We did not wish to limit our analysis to one or a couple of indicators of health and disability because we intend to investigate the general pattern of healthiness of survival and extent of suffering before dying with maximum utility of the available information. We, therefore, applied the GoM model in this article to analyze healthiness of survival and suffering before dying in order to maximize the use of available information, which is superior to the conventional latent analyses (Manton et al., 1994).

Several limitations deserve attention in interpretation of our findings. First, although the GoM scores of each individual on health profiles are superior to outcomes based on conventional methods, the results of the present study are not readily comparable with other GoM analyses of health status given that the typology obtained strongly relies on the choice of indicators and measurement instruments and that not all studies use the same instruments; nor do these instruments capture similar aspects of the health concept. Second, our longitudinal measures of the types of death include only several variables related to the quality of dying previously identified in the literature (Patrick et al., 2003; Steinhäuser, Clipp, & Tulskey, 2002). Third, related to the second, because the qualitative assessment of suffering before death is a key dimension of quality of death and the measure of suffering in the CLHLS was ascertained from the decedents' next of kin, the responses may be biased. Some research has shown that proxy reports are not always consistent with reports by individuals before their death (Hinton, 1996). Nevertheless, future studies should examine other assessments of suffering before dying as well as different sources and subjective dimensions of the quality of death faced by older adults (Dupre et al., 2009). Fourth, loss to follow-up from 1998 to 2000 was not random (Gu & Zeng, 2004), and thus, it may have introduced bias in our estimates. Although the GoM could produce unbiased health profiles if a respondent has some missing responses in study variables, it could not deal with the situation where a respondent does not have any data. Furthermore, multivariate analyses could automatically take the missing value or loss to follow-up into consideration. However,

supplementary analyses indicated that the general patterns and conclusions of our analysis did not change regardless of parameterizing the lost sample as a categorical outcome or imputing the missing cases. Fifth, associations between some behavioral factors and healthiness of survival and suffering before death presented in the study are very crude because these associations are likely very complicated and because the behavioral factors were coded dichotomously only. Further research on these associations is clearly warranted.

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Figure 1.

GoM (Grade of Membership) score in healthy survival in 2000 by GoM scores in different types in 1998

Figure 2.

Average GoM (Grade of Membership) scores of selected pure types in 2000 for those survivors by age, sex, and GoM score in healthy pure type in 1998: (a) average GoM scores (*gik*) for healthy type in 2000 (S1), (b) average GoM scores (*gik*) for cognitive moderately/severely impaired types (S3 and S4), (c) average GoM score in S1 in 2000 for those who had a 100% membership in S1 in 1998, and (d) average GoM score in S1 in 2000 for those who had a zero membership in S1 in 1998

Figure 3.

GoM (Grade of Membership) score in nonsuffering death in 1998–2000 by GoM scores in different types in 1998

Figure 4.

Average GoM scores of quality of death for the decedents by age, sex, and GoM scores healthy pure type in 1998: (a) average GoM scores for the type of Nonsuffering death (D1), (b) average GoM scores for types of Severely suffering (including medium-term and long-term; D4 and D5), (c) average GoM score in D1 in 2000 for those who had a 100% membership in S1 in 1998, and (d) average GoM score in D1 in 2000 for those who had a zero membership in S1 in 1998

Table 1

Distribution of Estimates of Probabilities (λ_{kij}^* 100) Describing the Six Dimensions of Health Conditions for Selected Variables in GoM Profiles at Baseline Survey in 1998

Selected variables	% in total sample	Dimension of health conditions					
		S1	S2	S3	S4	S5	S6
Needs no help in bathing	68.47	95.93	100.00	91.56	79.31	0.00	0.00
Needs no help in dressing	82.58	100.00	100.00	100.00	100.00	0.00	0.00
Needs no help in using toilet	80.73	100.00	100.00	100.00	100.00	0.00	0.00
Needs no help in indoor transferring	83.57	100.00	100.00	100.00	100.00	0.00	0.00
Able to control incontinence	91.16	100.00	100.00	100.00	100.00	47.70	60.58
Needs no help in eating	88.15	100.00	100.00	100.00	100.00	0.29	24.49
Able to put hands behind neck	88.03	100.00	96.68	100.00	100.00	31.12	51.87
Able to put hands behind low back	89.76	100.00	94.66	100.00	100.00	38.08	53.26
Able to stand from a chair without using hands	65.30	100.00	83.13	89.90	62.36	0.00	0.00
Able to pick up a book from the floor while standing	62.09	100.00	78.48	49.23	40.76	0.00	0.00
Able to turn around within 10 steps	56.23	85.32	75.60	58.05	22.59	0.00	0.00
Didn't suffer severe illness recent 2 years	89.21	94.93	91.65	97.49	97.38	56.83	62.35
Suffering from hypertension	13.14	15.73	7.12	7.24	7.12	22.44	6.56
Suffering from diabetes	0.87	0.79	0.00	0.00	0.00	2.75	1.88
Suffering from heart diseases	7.43	7.40	2.03	3.54	1.82	21.82	7.10
Suffering from CVD (cardiovascular disease)	3.19	0.00	0.00	0.00	0.00	24.90	8.23
Suffering from bronchitis, pneumonia	12.75	12.69	8.08	7.79	6.00	27.34	13.89
Suffering from TB	0.88	0.72	0.92	0.00	0.00	3.25	1.35
Suffering from cataract	19.19	12.39	6.49	8.47	11.73	63.66	37.34
Suffering from glaucoma	2.50	0.89	0.00	0.00	2.96	10.62	7.19
Suffering from cancer	0.49	0.30	0.00	0.00	0.00	2.37	1.11
Suffering from prostate tumor	4.71	5.58	2.75	0.00	0.00	10.66	4.39
Suffering from gastric or duodenal ulcer	3.30	3.53	1.21	1.40	1.33	7.84	2.68
Suffering from Parkinson's	0.99	0.54	0.96	0.12	0.00	4.79	2.00
Suffering from bedsores	0.87	0.44	0.00	0.00	0.00	2.99	3.73
Able to answer Orientation Question 1	86.16	100.00	100.00	92.66	77.59	97.76	0.00
Able to answer Orientation Question 2	76.52	100.00	99.30	42.41	29.02	90.23	0.00

Selected variables	% in total sample	Dimension of health conditions					
		S1	S2	S3	S4	S5	S6
Able to answer Orientation Question 3	79.20	100.00	99.66	42.54	33.66	100.00	0.00
Able to answer Orientation Question 4	79.24	100.00	100.00	46.74	33.52	100.00	0.00
Able to answer Orientation Question 5	77.95	100.00	100.00	38.54	39.80	80.42	0.00
Able to remember Object 1 instantly	74.54	100.00	100.00	0.00	20.82	94.23	0.00
Able to remember Object 2 instantly	68.12	95.41	95.28	0.00	3.75	75.98	0.00
Able to remember Object 3 instantly	68.26	94.39	98.89	0.00	5.95	75.78	0.00
Able to do Calculation 1	72.59	100.00	100.00	0.00	0.00	100.00	0.00
Able to do Calculation 2	61.76	100.00	99.13	0.00	0.00	99.82	0.00
Able to do Calculation 3	61.02	100.00	99.58	0.00	0.00	99.75	0.00
Able to do Calculation 4	57.17	100.00	96.78	0.00	0.00	100.00	0.00
Able to do Calculation 5	59.45	100.00	99.71	0.00	0.00	100.00	0.00
Able to drawing	26.76	53.37	22.81	0.00	0.00	0.00	0.00
Able to recall Object 1	59.26	100.00	100.00	0.00	0.00	100.00	0.00
Able to recall Object 2	56.51	100.00	89.15	0.00	0.00	100.00	0.00
Able to recall Object 3	54.61	100.00	92.27	0.00	0.00	100.00	0.00
Able to name Object 1	85.86	100.00	100.00	100.00	85.75	100.00	0.00
Able to name Object 1	85.28	100.00	100.00	100.00	80.75	100.00	0.00
Able to repeat sentence	69.62	100.00	96.42	0.00	0.00	100.00	0.00
Able to Listen and Obey 1	79.78	100.00	98.62	93.50	61.98	98.31	0.00
Able to Listen and Obey 2	78.23	100.00	100.00	100.00	58.62	88.09	0.00
Able to Listen and Obey 3	78.19	100.00	98.62	100.00	64.28	83.05	0.00

Note: There are 65 internal variables used in the GoM (Grade of Membership) model in this study. Variables listed in the table are the selected ones. Variables related to impacts of diseases on daily life and a few other variables are not listed in the table. We named dimension S1 as "healthy," S2 as "relatively healthy," S3 as "moderately cognitively impaired," S4 as "severely cognitively impaired," S5 as "full ADL (activities of daily living) dependent with fatal disease," and S6 as "extremely frail."

Table 2

Distribution of Estimates of Probabilities (λ_{kij}^* 100) Describing the Five Dimensions of Health Conditions Before Dying for Those Who Died From 1998 to 2000

Selected variables	% in total sample	Dimension of health conditions				
		D1	D2	D3	D4	D5
Bedridden before dying	69.87	44.72	55.19	87.60	100.00	100.00
Didn't suffer severe illness in recent 2 years	68.45	88.15	73.11	63.91	52.37	29.20
Suffered from hypertension before dying	7.13	5.69	7.53	7.83	9.38	8.90
Suffered from diabetes before dying	0.90	0.48	1.05	1.79	0.48	1.28
Suffered from heart diseases before dying	7.72	5.57	4.16	11.54	10.73	9.27
Suffered from CVD (cardiovascular disease)	8.61	5.79	5.42	7.39	14.24	16.15
Suffered from bronchitis, pneumonia before dying	10.16	7.27	10.04	14.13	12.72	12.34
Suffered from TB before dying	0.74	0.67	0.00	0.83	0.48	1.38
Suffered from glaucoma, cataract before dying	5.44	4.27	2.34	5.65	6.49	9.36
Suffered from prostate tumor before dying	1.30	1.47	1.14	0.80	1.72	1.18
Suffered from gastric or duodenal ulcer before dying	2.25	1.57	1.92	3.48	2.75	2.68
Suffered from Parkinson's disease before dying	0.34	0.00	2.18	0.00	0.00	0.98
Suffered from bedsores before dying	1.39	0.00	0.62	0.55	2.88	5.70
Suffered from dementia before dying	2.90	0.56	2.02	4.97	3.26	7.40
Suffered from psychosis before dying	0.43	0.29	1.64	0.73	0.00	0.27
Suffered from neurosis before dying	0.49	0.00	1.84	1.16	0.38	0.67
Suffered from arthritis before dying	4.45	2.45	6.38	7.43	6.05	4.88
Needed no help in bathing before dying	40.65	100.00	87.13	0.00	0.00	0.00
Needed no help in dressing before dying	51.04	100.00	100.00	0.00	0.00	0.00
Needed no help in using toilet before dying	48.68	100.00	100.00	0.00	0.00	0.00
Needed no help in indoor transferring before dying	47.71	100.00	100.00	0.00	0.00	0.00
Able to control incontinence before dying	69.07	100.00	92.70	46.68	23.87	26.96
Needed no help in eating before dying	60.03	100.00	81.29	18.63	0.00	0.00

Note: There are 35 variables used in GoM (Grade of Membership) model for those deceased respondents in this study. Variables related to period of staying in different ADL (activities of daily living) status and related to period of suffering from severe illness or bedridden are not listed in the table because of too many categories of each variable. We named dimension D1 as "nonsuffering," D2 as "slight suffering," D3 as "moderate suffering," D4 as "medium-term severe suffering," and D5 as "long-term severe suffering."

Table 3

Average Probabilities of Healthiness of Survival for Reinterviewed Survivors in 2000 and of Suffering Death for Those Deceased Persons From 1998 to 2000 According to the GoM Scores in 1998

Mean GIK scores of six pure types in 2000 calculated among survivors															Mean GIK score of five quality of death pure types calculated among the deceased persons from 1998 to 2000				
		S1	S2	S3	S4	S5	S6	Total	D1	D2	D3	D4	D5	Total					
GIK scores in 1998																			
Gi1	0.5	0.45	0.13	0.12	0.16	0.07	0.06	1.00	0.40	0.17	0.08	0.23	0.13	1.00					
Gi1	0.5~0.99	0.62	0.12	0.12	0.08	0.04	0.03	1.00	0.49	0.16	0.09	0.14	0.12	1.00					
Gi1	1	0.72	0.06	0.10	0.04	0.06	0.02	1.00	0.60	0.20	0.06	0.06	0.08	1.00					
Gi2	0.5	0.62	0.11	0.12	0.08	0.05	0.03	1.00	0.48	0.17	0.08	0.16	0.11	1.00					
Gi2	> 0.5	0.45	0.13	0.10	0.22	0.07	0.04	1.00	0.54	0.12	0.03	0.11	0.19	1.00					
Gi3	0.5	0.62	0.11	0.12	0.08	0.05	0.03	1.00	0.50	0.17	0.08	0.14	0.11	1.00					
Gi3	> 0.5	0.31	0.17	0.17	0.13	0.03	0.19	1.00	0.22	0.24	0.06	0.38	0.10	1.00					
Gi4	0.5	0.62	0.11	0.12	0.08	0.05	0.03	1.00	0.49	0.17	0.08	0.15	0.11	1.00					
Gi4	> 0.5	0.43	0.16	0.09	0.16	0.08	0.08	1.00	0.36	0.14	0.16	0.25	0.09	1.00					
Gi5	0.5	0.62	0.11	0.12	0.08	0.04	0.03	1.00	0.48	0.17	0.08	0.15	0.11	1.00					
Gi5	> 0.5	0.55	0.08	0.13	0.09	0.12	0.02	1.00	0.46	0.18	0.11	0.17	0.08	1.00					
Gi6	0.5	0.62	0.11	0.12	0.08	0.05	0.03	1.00	0.49	0.17	0.08	0.15	0.11	1.00					
Gi6	0.5	0.26	0.12	0.12	0.36	0.03	0.11	1.00	0.32	0.20	0.07	0.29	0.11	1.00					

Note: We named dimension S1 as "healthy," S2 as "relatively healthy," S3 as "moderately cognitively impaired," S4 as "severely cognitively impaired," S5 as "full ADL dependent with fatal disease," and S6 as "extremely frail"; D1 as "nonsuffering," D2 as "slight suffering," D3 as "moderate suffering," D4 as "medium-term severe suffering," D5 as "long-term severe suffering." Probabilities (i.e., Grade of Membership [GoM] scores) in the table are weighted ex post to more closely reflect the distribution of older adults in the population sampled (Manton, Gu, Huang, & Kovtun, 1994, p. 36).

Table 4
Multivariate Analyses of Healthiness of Survival and Suffering Death, CLHLS 1998–2000

	Models				
	1	2	3	4	5
Healthy survival					
Intercept	2.24 ***	2.17 ***	1.85 ***	1.31 ***	1.21 ***
Men	0.04 ***	0.01	-0.02	0.00	-0.03 ***
Age	-0.02 ***	-0.02 ***	-0.02 ***	-0.01 ***	-0.01 ***
Urban	0.02 **	0.00	-0.02 *	0.02 *	-0.01
Non-Han	-0.01	-0.01	0.02	-0.01	0.00
Having 1+ year of schooling		0.05 ***	0.03 **		0.02
Economic independence		0.06 ***	0.00		0.01
Married			0.06 ***		0.06 ***
Living alone			0.04 **		0.01
High social connection			0.07 ***		0.04 ***
Current smoking			-0.02 *		-0.03 **
Current heavy alcohol taking			0.04 **		0.03 *
Currently doing regular exercise			0.09 ***		0.05 ***
Optimistic			0.08 ***		0.02
Gi1 in 1998				0.35 ***	0.31 ***
Gi2 in 1998				0.07 *	0.06 *
Gi3 in 1998				-0.12 ***	-0.13 ***
Gi4 in 1998				0.03	0.03
Gi5 in 1998				0.21 ***	0.19 ***
Nonhealthy survival					
Intercept	0.46 ***	0.47 ***	0.44 ***	0.24 ***	0.23 **
Men	-0.09 ***	-0.08 ***	-0.09 ***	-0.09 ***	-0.09 ***
Age	0.00	0.00	0.00	0.00	0.00

	Models				
	1	2	3	4	5
Urban	0.00	0.01	0.00	0.01	0.01
Non-Han	0.04**	0.04**	0.05**	0.04*	0.04*
Having 1+ years of schooling		-0.02	-0.02		-0.02
Economic independence		0.01	0.01		0.01
Married			0.01		0.01
Living alone			0.00		0.00
High social connection			-0.02		-0.02
Current smoking			0.01		0.00
Current heavy alcohol taking			-0.04**		-0.04**
Currently doing regular exercise			0.03**		0.03*
Optimistic			0.01		-0.02
Gi1 in 1998				0.14***	0.15***
Gi2 in 1998				0.21***	0.21***
Gi3 in 1998				0.09***	0.10**
Gi4 in 1998				0.22***	0.22***
Gi5 in 1998				0.19***	0.21***
Nonsuffering death					
Intercept	-0.76***	-0.71***	-0.61***	-0.56***	-0.49***
Men	0.06***	0.08***	0.08***	0.07***	0.09***
Age	0.01***	0.01***	0.01***	0.01***	0.01***
Urban	-0.02	-0.01	0.00	-0.02	0.00
Non-Han	0.01	0.01	0.00	0.01	0.00
Having 1+ years of schooling		-0.01	0.00		0.00
Economic independence		-0.05***	-0.03		-0.03
Married			-0.05***		-0.05***
Living alone			0.01		0.02
High social connection			-0.02		-0.01
Current smoking			0.02		0.02*

	Models				
	1	2	3	4	5
Current heavy alcohol taking			0.01		0.02
Currently doing regular exercise			-0.03**		-0.03*
Optimistic			-0.02*		-0.01
Gi1 in 1998				-0.05	-0.04
Gi2 in 1998				0.11***	0.11***
Gi3 in 1998				0.04	0.04
Gi4 in 1998				0.05	0.05
Gi5 in 1998				-0.05	-0.05
Suffering death					
Intercept	-0.95***	-0.92***	-0.67***	0.00	0.05
Men	-0.01	0.00	0.02	0.02*	0.03**
Age	0.01***	0.01***	0.01***	0.01***	0.01***
Urban	-0.01	0.00	0.01	0.00	0.01
Non-Han	-0.05**	-0.05**	-0.07***	-0.04*	-0.04**
Having 1+ years of schooling		-0.02*	-0.01		0.00
Economic independence		-0.02	0.02		0.00
Married			-0.02		-0.02
Living alone			-0.06***		-0.02
High social connection			-0.04**		-0.01
Current smoking			0.00		0.01
Current heavy alcohol taking			-0.01		0.00
Currently doing regular exercise			-0.09**		-0.05**
Optimistic			-0.07**		0.01
Gi1 in 1998				-0.44***	-0.42***
Gi2 in 1998				-0.39***	-0.39***
Gi3 in 1998				0.00	-0.01
Gi4 in 1998				-0.31***	-0.31***

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	Models				
	1	2	3	4	5
Gi5 in 1998				−0.35***	−0.35***

Note: CLHLS = Chinese Longitudinal Healthy Longevity Survey. Results are based on multivariate analysis of covariance. Gi1 to Gi5 refer to GIK scores for five GoM types respectively.

* $p < .05$.
** $p < .01$.
*** $p < .001$.