東海大學統計學研究所
碩士論文

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Survival Analysis and the Effect of Education on Mortality of the Elderly in Taiwan

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ABSTRACT

With the advance of social economy and the system of medical treatment & health, the elderly people (65^+) have almost taken up 10% of the population in Taiwan, and problems of the elderly have become a major concern of public health. This research aims at survival analysis and the effect of education on mortality of old Taiwanese. Data come from the survey of Health and Living Status of the elderly in Taiwan held by Taiwan Provincial Institute of Family Planning in Department of Health during the period in 5 waves survey (1989, 1993, 1996, 1999 and 2003) from 1989 to 2003. This study investigate the survival status of 4,049 cases of the elderly with 15 variables related to demographic characteristics, health status, health behaviors, home & environment, and social participation with Cox proportional hazard model. The result shows that there 9 variables e.g. Age, Gender, Ethnicity, ADL (activity of daily living) function, Physical function, Self-rated health, Smoking, Chewing betel nut, and Spouse (marital status) are strongly related to the survival status of the elderly. Besides, a frailty model includes random component to account for extra variability from unobserved factors of the heterogeneity among individuals of Cox PH model is introduced. In addition, education mortality differentials at older ages is a topic of emerging interest. The impact of education on the mortality of the elderly in Taiwan is examined. We decompose the effect of education into the direct effect and the indirect effects by means of health status, health behaviors and social participation since the relationship between education and mortality involves a complex set of interrelations among various concepts. It shows that, of the total effect of education on the mortality of the elderly, about 65% represents indirect influences by the 3 mediating factors, particularly health status. On the other hand, the direct effect which might be affected by some additional interesting variables is not statistically significant. This is also hold where variable education is treated as categorical such as illiterate, elementary, junior high and senior high$^+$.

Key Words: survey of health and living status of the elderly, survival status, Cox proportional hazard model, frailty.

摘要

隨著社會經濟與醫療健康照護體系的進步，台灣老年人口(65 歲以上者)已超過 10%，老年人健康問題已成為公共衛生所主要關心的目標。另外，教育程度不同和老人死亡率之間的關係也是近年來新興的議題。本研究擬針對台灣地區老年人口進行存活分析並探討教育程度的差異對死亡率的影響。吾等採用前衛生署家庭計畫研究所起始於 1989 年之 5 波(1989、1993、1996、1999 及 2003)「臺灣地區老人保健與生活問題調查」資料，實際訪察 4,049 個案為研究對象蒐集其與背景特徵、健康狀況、健康行為、家庭環境、社會參與相關之 15 個變數進行 Cox 比例風險模式存活分析，結果顯示經由統計模式選擇，選出年齡、性別、族群、ADL(獨立活動能力)狀況、體能狀況、健康自評、抽煙、嚼食檳榔、有無配偶等 9 個變數為影響老人存活的重要指標當足以預測老人存活狀況;另外，我們亦考慮加入與個案間異質性及未被觀查到的隨機效果因子(frailty)於 Cox 比例風險模型中以調整其風險函數。至於教育程度差異與死亡率間的關係，基於死亡率乃係教育藉由社會、行為及健康相關因子所形成之函數，本研究將教育分解為對死亡率之直接影響及藉由健康狀況、健康行為及社會參與相關變數之間接影響。結果發現直接影響並不顯著而間接影響則佔有總影響之 65%，其中又以健康狀況因子之影響為最。另吾等將教育變數視為類別變項(文盲、小學、中學、高中職以上)也有著相同的結果，發現隨著教育程度的提高間接影響也隨之增加。

關鍵字:老人保健與生活問題調查、存活狀況、Cox 比例風險模式、frailty

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1. Introduction

With the advance of social economy and the system of medical treatment & health, the structure of population in Taiwan has from high fertility rate and high death rate reduced to a low fertility rate and low death rate. Life expectancy in Taiwan is increasing since the decreasing of low death rate. Now the elderly people (65^+) have almost taken up 10% of the population in Taiwan. Does “longevity” mean “more healthy”? This is the hot issue people want to know for the country with high ageing population. Some researchers indicate that female live longer than male; people who have spouses live longer than those who don’t; people with high socioeconomic status have lower hazard rate than those who with low socioeconomic status, etc. However, most of these studies are local area research 【Gove (1973); Hu & Goldman (1990); Tu (1985)】, and there have been less discussion on longitudinal study over a whole country. On the other hand, the influence of socioeconomic status on mortality is a concerned issue for demographer and educational attainment related to socioeconomic position has received increasing attention. Education is recognized as the most important socioeconomic determinant of mortality 【Antonovsky(1967); Elo & Preston(1996); Kitagawa & Hauser(1973); Pappas, Queen, Hadden, & Fisher(1993); Preston & Taubman(1994)】. There is considerable evidence that an individual’s educational attainment is more strongly correlated with diseases and health risks than occupation and income 【Kitagawa(1972); Preston & Taubman(1994); Winkleby, Jatulis, Frank, & Fortmann(1992)】. Understanding the patterns of educational differentials in mortality can provide insight into future mortality and health trends that may prove useful policies and programs.

This research aims at survival analysis and the effect of education on mortality of older Taiwanese. Data come from the survey of Health and Living Status of the elderly in Taiwan held by Taiwan Provincial Institute of Family Planning in Department of Health during the period from

1989 to 2003. The research uses 4,049 cases survival status in 5 waves survey (1989, 1993, 1996, 1999 and 2003) to analyze the survival status of elderly with 15 variables related to demographic characteristics, health status, health behaviors, home & environment, and social participation. Through survival analysis, Cox proportional hazard model is employed to find some important variables that affect people who are above 60 years old. Figure 1 is the framework of the survival analysis for this study. We assume survival status (until April, 2003) is related to demographic characteristics, health status, health behaviors, home & environment, and social participation in 1989. Also, we assume ADL (activity of daily living) function, physical function and self-rated health were good, never smoked and chewed betel nut; do outdoor activity and had spouse have lower hazard rate; the hazard rate of female is lower than male since the life expectancy of female is higher than male. Here, we define demographic characteristics, health status, etc. as factors, and age, gender, physical function, etc. as variables. For example, variables included in factor demographic characteristics are age, gender, ethnicity and level of education. Besides, a frailty model which is to incorporate an unmeasured "random" effect into the hazard function is considered for adjusting the heterogeneity of the subjects. In addition, the relationship between education and mortality involves a complex set of interrelations among various concepts. Mortality is a function of education through a number of intervening social, behavioral and biological factors. This study decomposes education to direct and indirect effects by means of health status, health behaviors and social participation to investigate the effect of education on mortality through the 3 pathways in 5 surveys during 1989-2003.

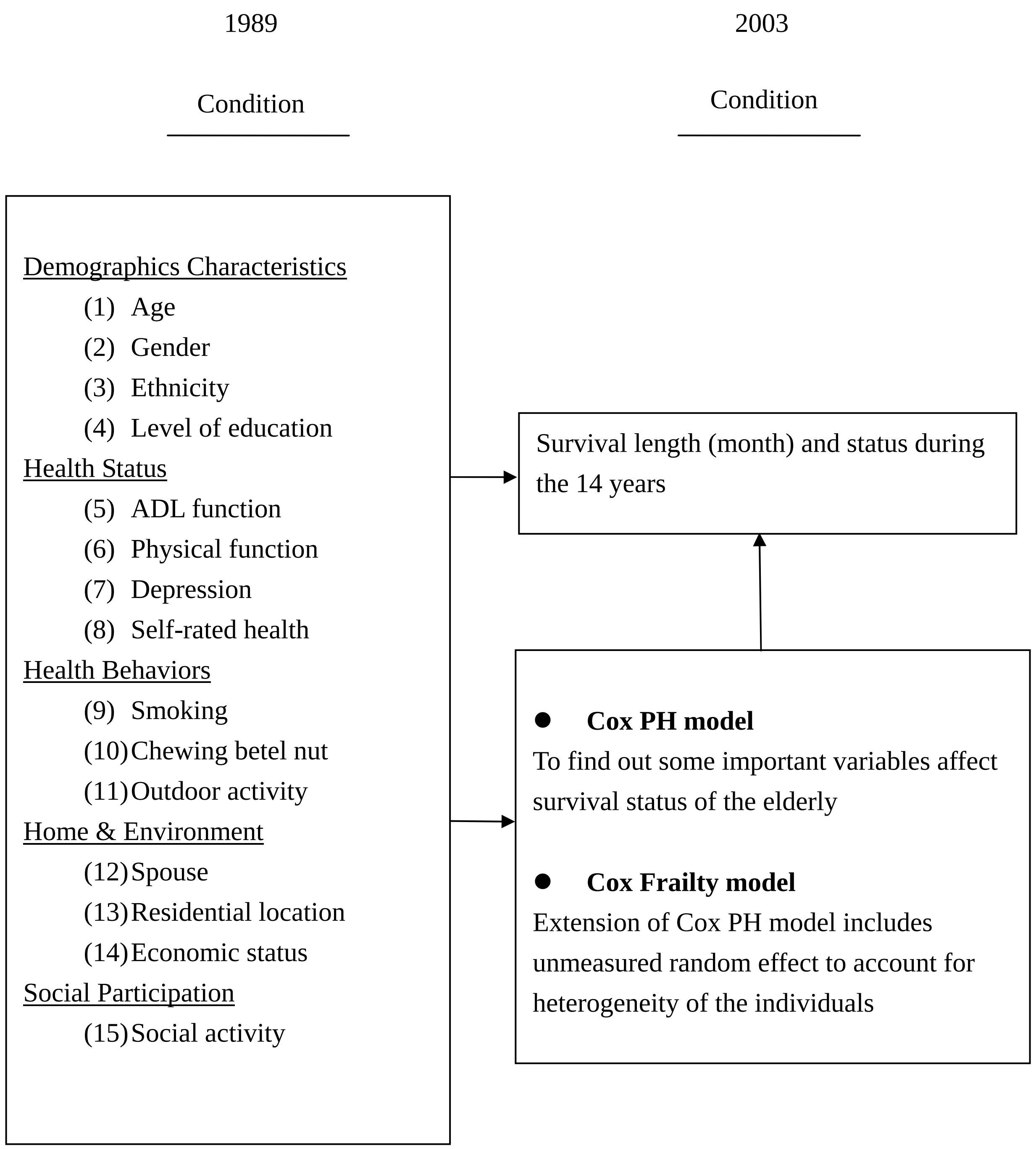

Figure 1 The effect of the factors on the survival status of Taiwanese elderly during 5 waves of survey from 1989 to 2003

2. Data and Method

2.1 Data description

This research adopts the survey of Health and Living Status of the elderly in Taiwan held by Taiwan Provincial Institute of Family Planning in Department of Health with assistance from the Population Studies Center and the Institute of Gerontology of The University of Michigan during the period from 1989 to 2003. The survey consisted of five waves (1989, 1993, 1996, 1999 and 2003). Respondents were adults 60 years of age or older in 1989 residing in the 331 non-aboriginal areas (countryside, town and city) of Taiwan, including those in institutions as well as regular households. The Wave 1 survey used a stratified three-stage probability sample, identifying 27 strata defined by three administrative levels, three levels of education, and three levels of the total fertility rate. The primary sampling unit was township, with block (Lin) as the second stage unit. Among 4,412 persons for the survey, 4,049 responded, yielding response rate of 91.8% and followed up in 1993, 1996, 1999 and 2003. We track the survival status of the respondents over the 14-year period for which death data are available, and basic demographic characteristics (e.g., age, gender, level of education), occupational history, social relationships, health status and health care utilization determinants of survival using information reported in five survey waves. All of death cases are connected to cause of death data file in Department of Health to get actual survival time (days) divided by 30 translate to month. Details of sampling and the questionnaire appear in the *1989 Survey of Health and Living Status of the Elderly in Taiwan: Questionnaire and Survey Design*【Hermalin, Liang, & Chang (1989)】.

Table 1 shows the characteristics of the 4,049 respondents at the time of the initial interview in 1989. The age ratio of the elderly from 60 to 69 years old takes up two-thirds. As for gender, male outnumber female in the ratio of three to two. Ethnically, the percentage of Fukien people comprises 60%; mainlander is one-forth; Hakka is 15% and aborigine is only 1.7%. Regarding education, most of the elderly have low level of education. The ratio of illiteracy is up to 40%; only one-fifth of the elderly have above junior high degrees. About the health status, over four-fifths of the elderly are in good condition in ADL function, physical function and depression; only one-third of the elderly are good in self-rated health. Regarding health behaviors, about half of the elderly are smokers; one-tenth of them are betel nuts chewers; 90% participated in outdoor activities in the past six months, like working on a farm, doing outdoor exercise or taking a walk. In relation to home & environment, about one-third of the elderly do not have spouses , half live in cities; one-third reside in countryside; one-fifth live in town and up to 80% have ideal economic status. In social participation, 40% of the elderly attended clubs.

Table 1 Characteristics and status of respondents at initial interview in 1989 (N=4,049)

		n	%			n	%
Age				*Self-rated health*			
	60-64	1482	36.60%		Good	1528	37.74%
	65-69	1152	28.45%		Fair	1494	36.90%
	70-74	725	17.91%		Poor	1027	25.36%
	75-79	438	10.82%	*Smoking*			
	80^+	252	6.22%		Yes	2014	49.74%
Gender					No	2035	50.26%
	Female	1738	42.92%	*Chewing betel nut*			
	Male	2311	57.08%		Yes	390	9.63%
Ethnicity					No	3659	90.37%
	Fukien	2477	61.18%	*Outdoor activity*			
	Hakka	603	14.89%		Yes	3612	89.21%
	Mainlander	900	22.23%		No	473	11.68%
	Aborigine	69	1.70%	*Spouse*			
Levels of education					Yes	2603	64.29%
	Illiterate	1685	41.62%		No	1446	35.71%
	Elementary school (1-6 years) /no formal education	1596	39.42%	*Residential location*			
					City	1917	47.35%
	Junior high school (7-9 years)	329	8.13%		Town	726	17.93%
	Senior high school$^+$ (10^+ years)	439	10.84%		Countryside	1406	34.72%
ADL function				*Economic status*			
	Good	3282	81.06%		Good	1683	41.57%
	Fair	624	15.41%		Fair	1524	37.64%
	Poor	143	3.53%		Poor	689	17.02%
Physical function					Missing	153	3.78%
	Good	3361	83.01%	*Social activity*			
	Fair	478	11.81%		Yes	1523	37.61%
	Poor	210	5.19%		No	2526	62.39%
Depression							
	Good	3342	82.54%				
	Fair	613	15.14%				
	Poor	94	2.32%				

2.2 Cox proportional hazard model for survival analysis

For the censoring problem, let T be the true lifetime and C denote the censoring time. For the censoring case we only observe that $X = \min(T, C)$ and $\delta = \mathbf{1}(T \le C)$, where $\mathbf{1}(\cdot)$ is the indicator function. The survival data available in regression problems for right-censored time data are independent observations on the triple (X, δ, Z) , where $Z = (Z_1, \cdots, Z_k)'$ is a vector of covariates. The vector Z may be a function of t, but the only requirement is that $Z(t)$ can be determined from the observations up to time (t).

Let T be a random variable representing lifetime. Then $F(t, Z_t) = \Pr(T \le t)$ is the cumulative distribution function, $f(t, Z_t) = dF(T, Z_t)/dt$ is probability density function and $S(t, Z_t) = \Pr(T > t) = 1 - F(t, Z_t)$ is called the survival function of T , where Z_t denoted as the vector for independent variables and could be either time-dependent or time-constant covariates.

The hazard function is expressed as follow:

$$h(t, Z_t) = \lim_{\Delta t \to 0} \frac{P(t \le T \le t + \Delta t \mid T \ge t, Z_t)}{\Delta t}$$
$$= \lim_{\Delta t \to 0} \frac{[F(t + \Delta t, Z_t) - F(t, Z_t)]/\Delta t}{P(T \ge t, Z_t)} = \frac{f(t, Z_t)}{S(t, Z_t)} . \quad (1)$$

The relationship among $h(t, Z_t)$, $f(t, Z_t)$ and $S(t, Z_t)$ are

$$S(t, Z_t) = \exp[-\int_0^t h(u, Z_u) du] \quad (2)$$

and

$$f(t, Z_t) = h(t, Z_t) \exp[-\int_0^t h(u, Z_u) du] \quad (3)$$

Cox (1972) proposed a proportional hazard model that specifies the hazard at time t for an individual as given by

$$h(t) = h_0(t)\exp\left(\sum_{i=1}^{p}\beta_i z_i\right) \tag{4}$$

where $h_0(t)$ is referred to as the baseline hazard function and $\beta = (\beta_1, \beta_2, ..., \beta_p)'$ are unknown parameters of interest.

Let $t_{(1)}, t_{(2)}, ..., t_{(k)}$ be the failure times. Denote $R(t)$ to be the set of individuals who are alive and uncensored at a time just prior to $t_{(i)}$. $R(t)$ is called the risk set. Intuitively, given $R(t_{(i)})$ the probability of an individual with covariate vector Z_i dying at $t_{(i)}$ is

$$\frac{h(t \mid Z_i)}{\sum_{l \in R(t_{(i)})} h(t \mid Z_l)} = \frac{e^{\beta^t Z_i}}{\sum_{l \in R(t_{(i)})} e^{\beta^t Z_l}} \tag{5}$$

Because the exact likelihood function depends on both the nonparametric function $h_0(t)$ and the parameter β, it might be difficult to estimate $h_0(t)$ and β simultaneously. To resolve this problem, one solution is to find a modified function involving only β. So, we can estimate β or make inferences about β based on the partial likelihood function. Thus, the partial likelihood function is given by

$$L(\beta) = \prod_{i=1}^{k}\left[\frac{e^{\beta' Z_i}}{\sum_{l \in R(t_{(i)})} e^{\beta' Z_l}}\right] \tag{6}$$

where i indicates k observed event times, $t_{(1)}, t_{(2)}, ..., t_{(k)}$. Survival analysis typically examines the relationship of the survival distribution to covariates.

Model (4) is called a semi-parametric model because a parametric form is assumed only for the covariate effect. Consider, the individuals i and j with covariates $Z_i = (Z_{i1}, Z_{i2}, \cdots, Z_{ik})$ and $Z_j = (Z_{j1}, Z_{j2}, \cdots, Z_{jk})$.

The ratio of hazards for the two individuals is

$$\frac{h_i(t)}{h_j(t)} = \frac{h_0(t)e^{\gamma_i}}{h_0(t)e^{\gamma_j}} = \frac{e^{\gamma_i}}{e^{\gamma_j}} = \exp\{\beta_1(Z_{i1} - Z_{j1}) + \ldots + \beta_k(Z_{ik} - Z_{jk})\} \tag{7}$$

which only depends on the difference between their linear predictor. The hazard ratio of any two individuals does not vary as the time changes.【Allison (1995)】

Cox proportional hazard model is the most popular for analyzing survival data which is based on the assumption that the hazard of event in the comparison group is a constant multiple of the hazard of event in the reference group. As for investigating proportional hazards assumption of Cox model Therneau, Grambsch, & Fleming (1990) suggested a method of analysis of residual used to make sure that there is no systematic structure remaining in the data. The residual plot for each variable should be no discernible patterns of any kind.

2.3 Inclusion of the frailty to a survival model

Frailty is a random component designed to account for extra variability from unobserved factors. The term frailty itself was introduced by Vaupel, Manton, & Stallard (1979) in univariate survival models and the model was substantially promoted by its application to multivariate survival data in a seminal paper by Clayton (1978) (without using the notion "frailty") on chronic disease incidence in families. The concept of frailty may be used to explain the unaccounted for heterogeneity which leads to the differential survival patterns of members of a population 【Keiding, Andersen, & Klein (1997), Vaupel et al. (1979)】. Frailty models are extensions of the proportional hazards model which is best known as the Cox model, the most popular model in survival analysis. It provides a convenient way to introduce random effects, association and unobserved heterogeneity into models for survival data. In its simplest form, a frailty is an unobserved random proportionality factor that modifies the hazard function of an individual, or of related individuals.

The frailty approach is a statistical modeling concept which aims to account for heterogeneity, caused by unmeasured covariates. One can distinguish two broad classes of frailty models: univariate frailty model and multivariate frailty model. In univariate frailty model (per subject basis) the unexplained heterogeneity varies from individual to individual and the frailty, the random effect, is an individual variable. In multivariate frailty model (grouping factor) the unexplained heterogeneity is shared among individuals and the frailty is a variable common to several individuals that are in units or groups chosen at random from the population (i.e. families, sibling groups). We focus on univariate case since the data in our research is on a per subject basis.

The frailty α is an unobserved multiplicative effect on the hazard function assumed to follow some distribution $g(\alpha)$ with $\alpha > 0$ and the mean of $g(\alpha)$ equal to 1. The variance of

$g(\alpha)$ is a parameter θ (theta) that is typically estimated from the data. In statistical terms, a frailty model is a random effect model for time-to-event data, where the random effect (the frailty) has a multiplicative effect on the baseline hazard function. Equation (8) is an individual's hazard function conditional on the frailty can be expressed as α multiplied by $h(t)$, so it could be lowers ($0 < \alpha < 1$) or increases ($\alpha > 1$) the individual risk.

$$h(t \mid \alpha) = \alpha \cdot h(t) = \alpha \cdot h_0(t)\exp(Z'\beta) \tag{8}$$

Another way to write the above model, showing how α fits into the error, e, is

$$h(t \mid \alpha) = h_0(t)\exp(Z'\beta + e)$$

where $e = \log(\alpha)$. Equation (9) using the relationship between the survival and hazard functions, the corresponding conditional survival function can be expressed as $S(t)$ raised to the α power.

$$S(t \mid \alpha) = S(t)^{\alpha} \tag{9}$$

Any distribution for $\alpha > 0$ with a mean of 1 can theoretically be used for the distribution of the frailty. The frailty distributions most often applied are the gamma distribution 【Clayton (1978); Vaupel et al.(1979)】, the positive stable distribution 【Hougaard (1986b)】, a three-parameter distribution (PVF) 【Hougaard (1986a)】, the compound poisson distribution 【Aalen (1988, 1992)】and the log-normal distribution 【McGilchrist & Aisbett (1991)】. Univariate frailty models are widely applied. With the mean fixed at 1, both these distributions are parameterized in terms of the variance θ and typically yield similar results.

2.4 Conceptual model of the effect of education on mortality of older Taiwanese

Educational mortality differentials at older is a topic of emerging interest. In the developed and some developing countries, most deaths occur at older ages 【Myers (1989); Yang (1993)】. Further improvement in life expectancy will occur mainly through mortality declines at older ages. If the inverse relationship between education and mortality persists throughout a person's life course, one might expect further enhancement in human longevity as younger cohorts generally achieve higher education attainment than older cohorts. At the same time, there is some empirical evidence showing diminishing impact with age of educational attainment on mortality, a phenomenon also observable in terms of some other risk factors such as race and gender 【Antonovsky (1967); Liu & Witten (1995); Manton & Stallard (1984); Vaupel et al. (1979)】. The process of human survival tends to select out more frail persons among the environmentally disadvantaged, so that the advantaged group (high level of education) eventually becomes more frail than their disadvantaged counterparts 【Vaupel (1990); Vaupel et al. (1979)】. When the change in population health composition is strong enough to offset the positive impact of favorable environment for the advantaged group, mortality convergence or crossover occurs. Other scholars argue that changes in an individual's behavior and physiological functions, and economic, social and medical developments in a society may also contribute substantially to mortality convergence at older ages 【Horiuchi (1989); Horiuchi & Wilmoth (1998); Khazaeli, Xiu & Curtsinger (1995)】. Whatever the cause of these changes, there is strong evidence that educational differentials in mortality vary over the life cycle 【Antonovsky (1967); Preston & Taubman (1994)】.

Zimmer, Martin, & Lin (2003) use Gompertz regression model to find the factor which affect the mortality of old Taiwanese in four waves survey during 1989-1999. In addition to investigate some variables effect on elderly mortality, they find effects of education are attenuated after adding some health related variables. With the same data, Lin & Lin (2006) use 15 independent variable, such as gender, ethnicity, level of education, residential location, economic status, spouse, physical function, ADL function, depression, etc. to investigate the factors associated with survival status of the elderly by six Cox proportional hazard models. Based on backward model selection, there are 10 variables related to survival status of the elderly in Taiwan. Also, they found level of education is not a significant variable related to mortality of the elderly. This is similar to the result of Zimmer et al. (2003). However, Liu, Hermalin, & Chuang (1998) indicated this might be owing to the indirect effect of education by means of health status, health behaviors and social relationships to affect the survival status of the elderly.

Liu et al. (1998) pointed out mortality is a function of education through a number of intervening social, behavioral and biological factors. Figure 2 shows the effect of education on mortality by health status, health behaviors and social relationships. Demographic characteristics are treated as exogenous factors. Health status, health behaviors and social relationships serve as the endogenous factors. The influence of education on mortality is mostly indirect 【House et al. (1992); Kitagawa & Hauser (1973); Preston & Taubman (1994); Winkleby et al.(1992)】. The residual direct impact of education on the mortality of older Taiwanese is illustrated with a dotted line in Figure 2. Liu et al. (1998) use two waves of survey during 1989~1993 to investigate the effect of education on elderly mortality and find out the effect of education are not significant in the model. They consider education through out health status, health behaviors and social relationships indirect to affect elderly mortality. Their research decomposes the effect of education on mortality into the direct effect and the indirect effects by means of health status, health behaviors and social relationships. The result shows education is insignificant and its direct effect is only 17% after adjusted by other variables. Health status, health behaviors and social relationships are 47.8%, 9.2% and 25.8% account for 83% of the indirect inference on education respectively and all significant. The relationship between education and mortality involves a complex set of interrelations among various concepts.

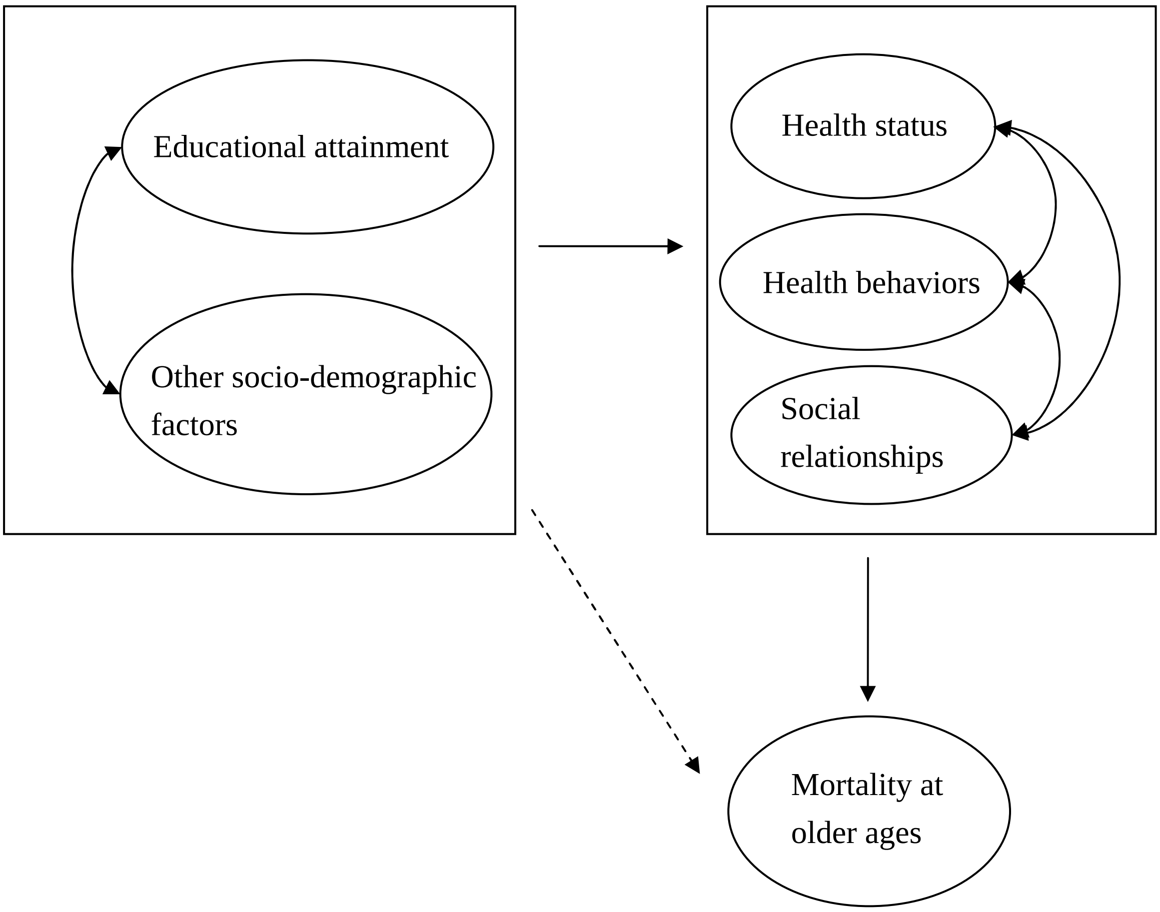

Figure 2　Causal model of factors affecting mortality of older Taiwanese　【Liu et al.(1998)】

Different from Liu et al. (1998) discuss two waves of survey, our research use five waves of survey during 1989-2003 with Cox proportional hazard model and investigate the trend of effect of education on elderly mortality. The following models will be used for exploring the direct and indirect effect of education on the mortality of the elderly in Taiwan.

Model 1: (Education+ other socio-demographic factors) + Health status + Health behaviors +

Social participation

Model 2: (Education+ other socio-demographic factors) + Health behaviors + Social participation

Model 3: (Education+ other socio-demographic factors) + Social participation

Model 4: (Education+ other socio-demographic factors)

According to the above models, four regression coefficients of education are adjusted by demographic variables, we decompose the effect of education into the direct effect and the indirect effects by means of health status, health behaviors and social participation then.

3. Measures

The outcome measure for this research is survival time, which is indicated by registry information on data of death. A series of demographic characteristics, health status, health behaviors, home & environment and social participation are considered as predictors of survival time. Demographic characteristics measures are age, gender, ethnicity and level of education. Health status measures are ADL function, physical function, depression and self-rated health. Health behaviors measures are smoking history, chewing betel nut history, and outdoor activity. Home & environment and social participation measures are spouse, residential location, economical status, and social activity. All the variables were used to assess the mortality of the elderly. Table 2 lists the variables used in the analytical model.

Most of the demographic characteristics, such as gender, ethnicity and level of education, do not change over time, but age do. All of the health characteristics, subject to change with time. An individual may develop a health problem or may recover from one. An individual who is married at one point in time may become widowed at a later date while still under observation. However, we do not have information on the exact day of a change in a covariate. Thus, we make use of the data provided from the most recent observation. Among the 15 variables, smoking and chewing betel nut are the actual total years of smoking and chewing betel nut. Other variables are treated as dummy variables. All the variables were used to assess the mortality of the elderly. Table 2 is the description of the variables used in the analytical model.

Table 2 Variables description and hypothesis in analytical model to assess the rate of death in elderly

Possible variables	Prospective influence to death
Age: according to birthday. Four dummy variables with five groups: "60-64", "65-69", "70-74", "75-79" and "80+"years old. "60-64" is the reference group.	More aged cause higher hazard rate
Gender: female denoted as 0; male denoted as 1.	Female has lower hazard rate than male
Ethnicity: three dummy variables with four groups: Fukien, Hakka, mainlander and aborigine. Fukien is the reference group	Mainlander have lower hazard rate than others
Level of education: measured as the total number of years in school. Three dummy variables with four groups: illiterate, elementary school (1-6 years in school) /self-taught, junior high school (7-9 years in school) and senior high school+ (10 or more years in school). Illiterate is the reference group.	Higher educational level and higher living standard have lower hazard rate
ADL function: the index of shopping, management money, making a telephone call and bathing. The summed scores [a] can be divided to good (10+), fair (5~9) or poor (0~4). Two dummy variables with three values: good, fair and poor. Good is the reference group.	Higher ADL function has lower hazard rate
Physical function: the index of walking up two or three flights of stairs, walking 200-300 meters,	Higher physical function value has lower hazard rate

doing physical work around the house, riding the bus or train, lifting, squatting, raising arms and twisting. The summed scores [a] can be divided to good (17^+), fair (8~16) or poor (0~7). Two dummy variables with three values: good, fair and poor. Good is the reference group.	
Depression: the index of feeling poor appetite, having bad mood, feeling not make a success of everything, poor sleeping, feeling lonely, feeling everyone not friendly and having no vitality to do everything. Then summed scores.	Higher depression score has higher hazard rate
Self-rated health: based on a question that asks respondents to rate their overall health as good (1, 2), fair (3) or poor (4, 5). Two dummy variables with three values. Good is the reference group.	Higher self-rated health value has higher hazard rate
Smoking: actual years of smoking	More years of smoking has higher hazard rate
Chewing betel nut: actual years of chewing betel nut	More years of chewing betel nut has higher hazard rate
Outdoor activity: never do outdoor activity denoted as 0; do outdoor activity denoted as 1.	Do outdoor activity has lower hazard rate
Spouse: married and spouse still alive denoted as 0, others denoted as 1.	Married with spouse has lower hazard rate
Residential location: two dummy variables with three locations: city, town and countryside. City is the reference group.	Living in city increases hazard rate

Economical status: two dummy variables with three values: good, fair and poor. Good is the reference group.	Poor economical status has higher hazard rate
Social activity: participating social club denoted as 0; don't participating social club denoted as 1.	Join social club has lower hazard rate

[a] Survey questions ask about the ability to carry out normal daily tasks. Respondents were asked about 12 such items in 1989 (shopping, management money, making a telephone call, bathing, walking up two or three flights of stairs, walking 200-300 meters, doing physical work around the house, riding the bus or train, lifting, squatting, raising arms and twisting); and for each, respondents were asked whether they could perform the task without difficulty, with a little difficulty, with a lot of difficulty, or not at all. To create the index we scored response for each individual activity from 0 to 3 (without difficulty=3; …; not at all=0). We then summed the scores for each index items.

4. Results

4.1 The survival analysis for the elderly in Taiwan

Based on the framework of Figure 1, we have 6 Cox proportional hazard models to interpret the elderly Taiwanese data. Table 3 is the results of regression coefficient and it exponentiated value hazard ratio of the six models. Model 1 contains regression estimates of variables related to demographic characteristics only. The following 3 models are estimates of the increased forms each adding variables related to factor health status, health behaviors and home environment & social participation from model 1 respectively. Model 5 is the full model includes all the 15 variables. Based on backward model selection in Model 5, we have parsimonious Model 6 in which 9 variables are significantly related to survival status.

The hazard ratios of all significant variables in Model 6 are explained as follows:

Age: Older people have higher hazard ratio than younger. The hazard ratio of age 80^+ is 4 times of age 60-64.

Gender: The hazard ratio of male is 1.6 times of female.

Ethnicity: The hazard ratio of mainlander is lower than others. The hazard ratio of mainlander is 0.77 times of Fukien's; the ratio of Hakka is 1.03 times of Fukien's; the ratio of aborigine is 1.02 times of Fukien's.

ADL function: The hazard ratio of common ADL function is 1.28 times of good's; the ratio of bad ADL function is 1.64 times of good's.

Physical function: The hazard ratio of common physical function is 1.45 times of good's; the ratio of bad physical function is 2.30 times of good's.

Self-rated health: The hazard ratio of common self-rated health is 1.20 times of good's; the ratio of bad self-rated health is 1.67 times of good’s.

Smoking: The more years smoking the higher hazard ratio get. The hazard ratio increased 1.006 times with increasing one-year smoking.

Chewing betel nut: The more years chewing betel nut the higher hazard ratio get. The hazard ratio increased 1.005 times with increasing one-year chewing betel nut.

Spouse: The hazard ratio of no spouse is 1.27 times of have spouse.

Table 4 compiles significant variables related to the survival status of the elderly of six Cox proportional hazard models. The nine variable of parsimonious survival Model 6 could be used for predicting the survival status of the elderly in Taiwan. Also, based on the residual plots of the analysis of residual for each variable are no discernible patterns of any kind (not shown), the proportional hazard assumption of the model seems reasonable.

Table 3 Results of hazard ratio on the mortality of older Taiwanese

		Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Variables		Coefficient	Hazard ratio	Coefficient	Hazard ratio	Coefficient	Hazard ratio	Coefficient	Hazard ratio	Coefficient	Hazard ratio	Coefficient	Hazard ratio
Age	60-64	0	1	0	1	0	1	0	1	0	1	0	1
	65-69	0.393***	1.482	0.377***	1.457	0.381***	1.464	0.389***	1.461	0.353***	1.423	0.348***	1.416
	70-74	1.007***	2.736	0.921***	2.513	0.983***	2.671	0.974***	2.614	0.874***	2.396	0.896***	2.449
	75-80	1.418***	4.129	1.273***	3.570	1.394***	4.031	1.383***	3.895	1.205***	3.338	1.216***	3.372
	80+	1.822***	6.187	1.427***	4.167	1.812***	6.121	1.636***	5.057	1.344***	3.834	1.380***	3.976
Gender	Male	0.490***	1.633	0.631***	1.880	0.265***	1.303	0.548***	1.691	0.499***	1.646	0.448***	1.566
	Female	0	1	0	1	0	1	0	1	0	1	0	1
Ethnicity	Fukien	0	1	0	1	0	1	0	1	0	1	0	1
	Hakka	0.028	1.028	0.019	1.019	0.014	1.014	0.039	1.036	0.035	1.036	0.024	1.025
	Mainlander	-0.199**	0.820	-0.199**	0.819	-0.184**	0.832	-0.222***	0.829	-0.228***	0.796	-0.258***	0.772
	Aborigine	0.349*	1.418	0.271	1.311	0.061	1.062	0.272	1.317	0.084	1.088	0.022	1.023
Education	Illiterate	0	1	0	1	0	1	0	1	0	1		
	Elementary school	-0.210***	0.810	-0.102	0.903	-0.201***	0.818	-0.146**	0.873	-0.091	0.913		
	Junior high school	-0.368***	0.692	-0.192	0.825	-0.317**	0.729	-0.274**	0.765	-0.145	0.865		
	Senior high school +	-0.371***	0.690	-0.215*	0.807	-0.285**	0.752	-0.250**	0.798	-0.131	0.877		
ADL function	Good			0	1					0	1	0	1
	Fair			0.243***	1.275					0.200**	1.221	0.245***	1.277
	Poor			0.481***	1.617					0.401**	1.493	0.492***	1.636
Physical function	Good			0	1					0	1	0	1
	Fair			0.395***	1.484					0.384***	1.469	0.371***	1.449
	Poor			0.807***	2.241					0.839***	2.313	0.832***	2.298
Depression				-0.008	0.992					-0.005	0.995		
Self-rated health	Good			0	1					0	1	0	1
	Fair			0.197***	1.217					0.187***	1.206	0.185***	1.203
	Poor			0.552***	1.737					0.513***	1.670	0.511***	1.667
Smoking						0.006***	1.006			0.006***	1.006	0.006***	1.006
Chewing betel nut						0.006**	1.006			0.005*	1.005	0.005*	1.005
Outdoor activity	Yes					-0.268**	0.76			-0.128	0.880		
	No					0	1			0	1		
Spouse	Yes							0	1	0	1	0	1
	No							0.211***	1.246	0.236***	1.27	0.238***	1.269
Residential location	City							0	1	0	1		
	Town							-0.063	0.93	-0.097	0.908		
	Countryside							0.029	1.008	-0.026	0.974		
Economic status	Good							0	1	0	1		
	Fair							0.104*	1.099	0.026	1.026		
	Poor							0.225***	1.245	-0.051	0.950		
Social activity	Yes							0	1	0	1		
	No							0.132**	1.152	0.070	1.072		
-2lnlikelihood		32777.986***		31951.915***		31893.707***		32605.266***		31103.384***		31221.667***	
Sample population: 4049													

p<.05; **p<.01;*p<.001*

Table 4 Significant variables related to the elderly of six Cox proportion models

Model (Factor)	Variables
1. Demographic characteristics	Age, gender, ethnicity (mainlander vs. Fukien; aborigine vs. Fukien) and level of education are significant
2. Demographic characteristics + health status	Age, gender, ethnicity (mainlander vs. Fukien), level of education (senior high school+ vs. illiterate), ADL function, physical function and self-rated health are significant Variable level of education (junior high school vs. illiterate) is marginal significant Variable depression is insignificant
3. Demographic characteristics + health behaviors	Age, gender, ethnicity (mainlander vs. Fukien), level of education, smoking, chewing betel nut and outdoor activity are significant
4. Demographic characteristics + home & environment + social participation	Age, gender, ethnicity (mainlander vs. Fukien), level of education, spouse, economical status and social activity are significant Variable residential location is insignificant
5. Full model Demographic characteristics + health status + health behaviors+ home & environment + social participation	Age, gender, ethnicity (mainlander vs. Fukien), ADL function, physical function, self-rated health, smoking, chewing betel nut and spouse are significant Level of education, depression, outdoor activity, residential location, economical status and social activity are insignificant

6. Parsimonious model based on model selection of Model 5	Age, gender, ethnicity, ADL function, physical function, self-rated health, smoking, chewing betel nut and spouse

4.2 Comparison of Cox proportional hazard model and Cox frailty-gamma model

To account for such unobserved heterogeneity in the study population Vaupel et al. (1979) introduced univariate frailty models into survival analysis. Output from running a Cox proportional hazard model without frailty (Model 6) and Cox frailty-gamma model is shown on Table 5. Cox frailty-gamma model is the same model as Cox proportional hazard model except that a frailty component has been included. The frailty in Cox frailty-gamma model is assumed to follow a gamma distribution with mean 1 and variance equal to theta (θ). Because the gamma distribution is a two-parameter distribution and the mean is set at 1, we need only estimate its variance to fully specify the frailty distribution. The estimate of theta is 0.353. Likelihood ratio test for the hypothesis theta=0 in Table 6 indicates a highly significant p-value. This means the frailty model would be more suitable for our data than Cox proportional hazard model. Notice all the parameter estimates are altered with the inclusion of the frailty. The inclusion of frailty has an impact on the parameter estimates. Also, we compute the percent relative efficiency of var($\hat{\beta}_s$)/var($\hat{\beta}_f$), which is based on the estimator $\hat{\beta}_f$ in the frailty-gamma model with respect to based on the estimator $\hat{\beta}_s$ in the Cox PH Model.

Table 5 Fit of the Cox proportional hazard model and frailty-gamma model

Method		Cox PH Model				Cox frailty-gamma Model				Diff in Coeff.[a]	Percent Relative Efficiency[b]
variable		coef.	s.e.	wald χ^2	p	coef.	s.e.	wald χ^2	p		
Age	65-69	0.353	0.0642	30.21	3.90E-08	0.388	0.0704	30.45	3.40E-08	0.036	83.19
	70-74	0.905	0.0673	181.06	0.00E+00	1.007	0.0760	175.78	0.00E+00	0.102	78.43
	75-80	1.204	0.0764	248.19	0.00E+00	1.378	0.0887	241.33	0.00E+00	0.174	74.22
	80^+	1.382	0.0958	207.97	0.00E+00	1.579	0.1151	188.17	0.00E+00	0.198	69.23
Gender	Male	0.458	0.0689	44.17	3.00E-11	0.529	0.0787	45.24	1.70E-11	0.071	76.72
Ethnicity	Hakka	0.045	0.0639	0.49	4.80E-01	0.055	0.0735	0.55	4.60E-01	0.010	75.51
	Mainlander	-0.274	0.0633	18.74	1.50E-05	-0.306	0.0717	18.27	1.90E-05	-0.032	77.98
	Aborigine	0.038	0.1743	0.05	8.30E-01	0.009	0.2071	0.00	9.60E-01	-0.029	70.83
ADL function	Fair	0.258	0.0667	14.95	1.10E-04	0.315	0.0786	16.00	6.30E-05	0.057	71.94
	Poor	0.393	0.1337	8.62	3.30E-03	0.471	0.1719	7.51	6.10E-03	0.078	60.49
Physical function	Fair	0.375	0.0741	25.63	4.10E-07	0.437	0.0874	24.98	5.80E-07	0.062	71.91
	Poor	0.849	0.1166	53.01	3.30E-13	0.974	0.1497	42.36	7.60E-11	0.125	60.64
Self-rated health	Fair	0.190	0.0546	12.09	5.10E-04	0.218	0.0617	12.50	4.10E-04	0.028	78.41
	Poor	0.502	0.0637	62.17	3.10E-15	0.601	0.0742	65.51	5.60E-16	0.099	73.55
Smoking		0.006	0.0014	18.89	1.40E-05	0.007	0.0016	21.06	4.50E-06	0.001	75.18
Chewing betel nut		0.005	0.0022	5.78	1.60E-02	0.006	0.0026	5.59	1.80E-02	0.001	67.97
Spouse	No	0.238	0.0504	22.23	2.40E-06	0.298	0.0579	26.50	2.60E-07	0.061	75.66
Theta						0.353					

[a] $\hat{\beta}_f - \hat{\beta}_s$; [b] $100 \cdot [\hat{SE}_s^2 / \hat{SE}_f^2]$

Table 6 Likelihood ratio test for the hypothesis theta=0

Log L No frailty	Log L frailty	L.R. χ^2	p-value	Var of frailty
-14981.71	-14974.5	14.42	<.001	0.353

4.3 The effect of education on mortality of the elderly

The model used for exploring the effect of education on mortality of the old people is similar to the parsimonious 9 variables survival model of former section except they have one more variable social activity. Here we use education to investigate the trend of Model 7.1 (direct effect) and Model 7.4 (total effect) to illustrate the effect of educational attainment on elderly mortality. Table 7 shows the result of four hazard rate regression models. The model 7.1 in Table 7 is a full model with both exogenous (level of education and other demographic characteristics) and mediating (health status, health behaviors and social relationships) variables included, which estimate the direct effect of education on the mortality of Taiwanese elderly. The influence of education on mortality is mostly indirect mediated by health status, health behaviors and social relationships. The following three models (Model 7.2-7.4) are the estimates of the reduced forms with each omitting a mediating factor from the previous model. Model 7.1 presents the direct effect of education on the death rate while Model 7.4 presents the total effect of education on the mortality data. The regression coefficients of education in all four models are all negative. This means the hazard rate decreases when years of education increase. Model 7.1 shows the smallest effect of education on the coefficient (-0.00867) and Model 7.4 the largest (-0.02464). The exponentiated value of $100(e^b - 1)$ gives the percentage change in the hazard ratio with one-unit change in education. In Model 7.4 the value of e^b for education is $e^{-0.02464} = 0.976$ means a 2.4% reduction in the death rate over 14 years with a 1-year increase in education, after controlling for age, gender, ethnicity and spouse.

Table 8 is the decomposition of the total effect of education on the mortality of Taiwanese elderly between 1989 and 2003. Of the total effect of educational attainment on mortality (-0.02464), about 65% represents indirect influences by means of health status, health behaviors and social participation. Health status, consisting of three major dimensions in our research--ADL function, physical function and self-rated health--is shown to be the leading factor transmitting the impact of education on the mortality. There is about 46% of the educational influences on mortality operate through health status while controlling for other 3 factors. Health behaviors, consisting of two variables in our research--years of smoking and years of chewing betel nut--represents 10% of the total effect. As for social activity belonged to social participation factor which represents 9% of the total effect. Besides treated education as a continuous variable, we consider the categorical variable education as 4 levels: illiterate, elementary, junior high and senior high^{+} and find out the percent of indirect effect increases with higher level of education. The results are shown from Table 9 to Table 12.

Table 7 Results of hazard rate regression on the mortality of older Taiwanese between 1989 and 2003 with continuous variable education

		MODEL 7.1			MODEL 7.2			MODEL 7.3			MODEL 7.4		
Variables		Coefficient		Hazard ratio	Coefficient		Hazard ratio	Coefficient		Hazard ratio	Coefficient		Hazard ratio
Age	60-64	0		1	0		1	0		1	0		1
	65-69	0.350	***	1.420	0.370	***	1.447	0.384	***	1.468	0.379	***	1.461
	70-74	0.891	***	2.437	0.977	***	2.657	0.991	***	2.693	0.985	***	2.678
	75-80	1.209	***	3.349	1.366	***	3.919	1.375	***	3.954	1.371	***	3.940
	80+	1.366	***	3.918	1.723	***	5.600	1.710	***	5.531	1.718	***	5.574
Gender	Male	0.499	***	1.647	0.320	***	1.378	0.543	***	1.722	0.518	***	1.678
	Female	0		1	0		1	0		1	0		1
Ethnicity	Fukien	0		1	0		1	0		1	0		1
	Hakka	0.030		1.031	0.028		1.028	0.032		1.032	0.027		1.028
	Mainlander	-0.232	***	0.793	-0.222	***	0.801	-0.248	***	0.781	-0.254	***	0.776
	Aborigine	0.063		1.065	0.110		1.116	0.366	*	1.441	0.333	*	1.396
Spouse	Yes	0		1	0		1	0		1	0		1
	No	0.236	***	1.266	0.228	***	1.256	0.237	***	1.268	0.241	***	1.273
Education		-0.00867		0.991	-0.01997	**	0.980	-0.02248	***	0.978	-0.02464	***	0.976
ADL function	Good	0		1									
	Fair	0.226	***	1.253									
	Poor	0.476	***	1.609									
Physical function	Good	0		1									
	Fair	0.374	***	1.453									
	Poor	0.846	***	2.330									
Self-rated health	Good	0		1									
	Fair	0.183	***	1.201									
	Poor	0.502	***	1.651									
Smoking		0.005	***	1.005	0.006	***	1.006						
Chewing betel nut		0.005	*	1.005	0.006	**	1.006						
Social activity	Yes	0		1	0		1	0		1			
	No	0.075		1.078	0.146	**	1.157	0.153	***	1.165			
-2 Log Likelihood		31119	***		31851	***		32718	***		32729	***	

**p<.05; **p<.01; ***p<.001*

Table 8 Decomposition of total effect of educational attainment on mortality into direct and indirect effects

Type of Effect	Magnitude of effect	Percent of effect
Total effect	-0.02464***	100.00%
Direct effect	-0.00867	35.19%
Indirect effect	-0.01597***	64.81%
Health status	-0.01130***	45.86%
Health behaviors	-0.00251***	10.19%
Social participation	-0.00216**	8.77%

***p<.01; ***p<.001*

Table 9 Results of hazard rate regression on the mortality of older Taiwanese between 1989 and 2003 with dummy variable education

		MODEL 7.1			MODEL 7.2			MODEL 7.3			MODEL 7.4		
Variables		Coefficient		Hazard ratio	Coefficient		Hazard ratio	Coefficient		Hazard ratio	Coefficient		Hazard ratio
Age	60-64	0		1	0		1	0		1	0		1
	65-69	0.348	***	1.416	0.363	***	1.438	0.380	***	1.463	0.377	***	1.457
	70-74	0.884	***	2.421	0.958	***	2.606	0.976	***	2.655	0.971	***	2.640
	75-80	1.204	***	3.335	1.351	***	3.862	1.365	***	3.916	1.362	***	3.906
	80+	1.358	***	3.890	1.701	***	5.479	1.695	***	5.445	1.704	***	5.495
Gender	Male	0.514	***	1.671	0.351	***	1.420	0.577	***	1.780	0.552	***	1.736
	Female	0		1	0		1	0		1	0		1
Ethnicity	Fukien	0		1	0		1	0		1	0		1
	Hakka	0.037		1.038	0.043		1.044	0.043		1.044	0.039		1.040
	Mainlander	-0.220	**	0.802	-0.200	**	0.819	-0.226	***	0.798	-0.231	***	0.793
	Aborigine	0.072		1.074	0.128		1.137	0.390	*	1.477	0.360	*	1.434
Spouse	Yes	0		1	0		1	0		1	0		1
	No	0.237	***	1.268	0.229	***	1.258	0.238	***	1.269	0.243	***	1.275
Education	illiterate	0		1	0		1	0		1	0		1
	elementary	-0.094		0.910	-0.207	***	0.813	-0.196	***	0.822	-0.208	***	0.812
	junior	-0.148		0.862	-0.321	**	0.726	-0.334	***	0.716	-0.350	***	0.704
	senior+	-0.135		0.874	-0.282	**	0.754	-0.315	***	0.730	-0.345	***	0.708
ADL function	Good	0		1									
	Fair	0.214	**	1.239									
	Poor	0.464	***	1.590									
Physical function	Good	0		1									
	Fair	0.371	***	1.449									
	Poor	0.848	***	2.335									
Self-rated health	Good	0		1									
	Fair	0.180	**	1.198									
	Poor	0.501	***	1.650									
Smoking		0.006	***	1.006	0.006	***	1.006						
Chewing betel nut		0.005	*	1.005	0.006	**	1.006						
Social activity	Yes	0		1	0	**	1	0		1.000			
	No	0.074		1.077	0.144		1.155	0.152	**	1.165			
-2 Log Likelihood		31117	***		31842	***		32711	***		32721	***	

**p<.05; **p<.01; ***p<.001*

Table 10 Decomposition of total effect of educational attainment in elementary school on mortality into direct and indirect effects with illiterate as a reference group

Elementary school	**Type of Effect**	**Magnitude of effect**	**Percent of effect**
	Total effect	-0.208***	100.00%
	Direct effect	-0.094	45.21%
	Indirect effect	-0.114***	54.79%

	Health status	-0.112***	53.94%
	Health behaviors	0.010***	-4.91%
	Social participation	-0.012**	5.76%

***p<.01; ***p<.001*

Table 11 Decomposition of total effect of educational attainment in junior high school on mortality into direct and indirect effects with illiterate as a reference group

	Type of Effect	**Magnitude of effect**	**Percent of effect**
Junior high school	**Total effect**	-0.350***	100.00%
	Direct effect	-0.148	42.27%
	Indirect effect	-0.202***	57.33%
	Health status	-0.173***	49.29%
	Health behaviors	-0.013***	3.81%
	Social participation	-0.016**	4.63%

***p<.01; ***p<.001*

Table 12 Decomposition of total effect of educational attainment in senior high school+ on mortality into direct and indirect effects with illiterate as a reference group

	Type of Effect	**Magnitude of effect**	**Percent of effect**
Senior high school+	**Total effect**	-0.345***	100.00%
	Direct effect	-0.135	39.15%
	Indirect effect	-0.210***	60.85%
	Health status	-0.147***	42.60%
	Health behaviors	-0.033***	9.56%
	Social participation	-0.030**	8.69%

***p<.01; ***p<.001*

5. Conclusion

The research investigates 15 variables related to 4,049 elderly cases survival status of the elderly during 1989 to 2003 in Taiwan through backward model selection of Cox proportional hazard model and find some significant variables such as age, gender, ethnicity, ADL function, physical function, self-rated health, smoking, chewing betel nut and spouse to affect the survival status of the people who are above 60 years old. These variables verify the assumption that ADL function, physical function and self-rated health were good, never smoked, chewed betel nut, do outdoor activity, female, younger age and had spouse in 1989 have lower hazard rate. They are good prediction index for survival status of the elderly in Taiwan. Residual plots for each variable (not shown) show that the proportional hazard assumption of the Cox model is reasonable. Also, the Cox model with gamma frailty includes extra variability from unobserved factors might be more suitable than the standard Cox PH model to our data. Table 5 is the result of difference between the 2 models.

Education is widely perceived as the single most important socioeconomic determinant of mortality. Education attainment would influence mortality through its effects on health status, health behaviors and social participation. This research decomposes the effect of education into the direct effect and the indirect effects by means of health status, health behaviors and social participation. The effect of education attainment on the mortality of the elderly Taiwanese, about 65% represents indirect influences by the 3 mediating factors, particularly health status. Education has a moderate but clear association with ADL function, physical function and self-rated health, as might be expected from a more education person will benefit from higher income, safer occupations, less environmental risks, better housing and great access to health care resources. Health status in 1989 is strongly predictive of survival status over the 14-year period. Consequently, Health status account for most of the indirect effect of education on mortality.

Health behaviors have a moderate relationship between education and mortality among the elderly Taiwanese. The more educated persons are less likely to be smokers and betel nut chewer, smoking and chewing betel nut have a strong negative effect on survival. Both linkage patterns contribute to higher survival rate for more educated people. As a consequence, health behaviors account more than 10% of the indirect effect of education on mortality. There is a moderately positive and significant relationship between social participation and education, in turn, contributes indirectly to the mortality differentials by educational attainment. About 9% of the indirect effect of education on mortality is accounted through social participation. Besides treated education as a continuous variable, we consider the categorical variable education as 4 levels: illiterate, elementary, junior high and senior high$^+$ and find out the percent of indirect effect increases with higher level of education.

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