The effectiveness of body-mass index, calf circumference and mid arm circumference in predicting subsequent mortality risk in elderly Taiwanese

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Abstract

Body-mass index (BMI), mid-arm circumference (MAC) and calf circumference (CC) are anthropometric indicators often included in geriatric health measurement scales. However, their relative effectiveness in predicting long term mortality risk has not been extensively examined. This study was aimed to evaluate the relative effectiveness of these anthropometrics in predicting long-term mortality risk in older adults. The study prospectively analyzed the ability of these indicators in predicting follow-up four-year mortality risk of a population-representative sample of 4191 men and women, 53 years of age or older in the "Survey of Health and Living Status of the Elderly in Taiwan". Cox regression analyses were performed to evaluate the association of follow-up mortality risk with low (<21 kg/m^2) or high (≥27 kg/m^2) BMI, low MAC (<23.5/22 cm for men/women) and low CC (<30/27 cm), respectively, according to Taiwanese-specific cut-points. Results showed that low CC and low MAC were more effective than low BMI in predicting follow-up mortality risk in 65-74 years old elderly. But, low CC and low BMI were more effective than low MAC in ≥75-years old elderly and low BMI was more effective than low MAC or low CC in 53-64 years old persons. High BMI was not effective in predicting mortality risk in any of these age ranges. These results suggest that in elderly adults, CC is more effective than BMI in predicting long-term mortality risk. Thus, more consideration to CC and MAC in designing geriatric health or nutritional measurement scales is recommended.

Introduction

Extreme body-weight, either excessive or inadequate, possesses health risk. Excessive body-weight or obesity is a major risk factor of hypertension, dyslipidemia, type-2 diabetes and heart disease whereas underweight is often associated with weakened immune competency, increased risk of infection and poor physical functional ability[1-3]. Weight change is also associated with changes in the extremities such as mid-arm (MAC) and calf circumferences (CC). Many factors such as aging, physical activity, nutrition and chronic health conditions can influence the size of these circumferences[4].

Body-mass index (BMI, calculated from height and weight according to kg/m^2) is usually considered an indicator of body fatness because weight gain is usually associated with fat gain. MAC and CC reflect body muscle mass in addition to subcutaneous fat thus, are indicative of physical functional ability and body fatness[5].

Advanced aging is often accompanied by unplanned weight loss and body protein loss, a process called sarcopenia which is often associated with functional decline[6]. Thus, excessive weight loss rather than excessive weight gain is more of a concern in geriatric health. Monitoring changes in weight (or BMI) and circumferences of extremities such as arm and calf, therefore, is particularly useful in geriatric care

Because BMI, MAC and CC can reflect weight loss and functional decline in older adults, these indicators have been included in scales for assessing health or nutritional status of frail or hospitalized persons[7]. However, the relative ability of these indicators in predicting functional status or long term mortality has not been extensively examined, especially in Eastern populations. In this study, we compared the ability of BMI, MAC and CC in predicting long-term mortality risk in older Taiwanese.

Methods

This study analyzed 1999 and 2003 data of the "Survey of Health and Living Status of the Elderly in Taiwan" (SHLSET), a population-representative longitudinal cohort study conducted by the Bureau of Health Promotion of the Department of Health of Taiwan. This on-going cohort study was initiated in 1989 for gaining an understanding of the role of socioeconomic, environmental, lifestyle and healthcare parameters on health, well-being and quality of life of older Taiwanese[8]. The design and sampling process of the project is available at a government website[9] and the key steps are outlined in Fig. 1. The study employed a multi-stage national probability sampling process. The entire population in Taiwan was first stratified into 361 administrative units (primary sampling units, PSU). After excluding 30 lightly populated mountainous (aboriginal) areas, the remaining 331 PSU were stratified into 27 strata of roughly equal population sizes and 56 PSU were chosen based on proportion-to-size random selections. Stage 2 involved proportion-to-size selections of blocks (lins, the primary administrative unit) from selected PSU and the final stage involved random selections of two eligible persons, 60 years of age or older, from each of the selected lins. The process selected 4412 elderly men and women ≥60 years of age to serve as subjects.

In 1996, a second sampling of 2462 subjects, 50-66 years old, selected with the same process was added to the cohort. Subjects in the cohort were interviewed every 3 to 4 years (in 1989, 1993, 1996, 1999, 2003 and 2006) with a core questionnaire. Each survey also contained additional questionnaires for specific purposes. Data up to the 2003 survey have been released for academic studies.

In each survey, trained interviewers conducted in-home face-to-face interviews. The 1999 survey involved all available (4915) participants in the cohort and the youngest was 53 years old.

Only the 1999 survey included data of all three (BMI, MAC and CC) anthropometric measurements and therefore was chosen as the baseline data set of the present analysis. The 2003 survey, the latest data set available, served as end-point. Data were analyzed with the Statistical Package for the Social Sciences (SPSS version 14.0. Chicago, IL). Self-reported height and weight at baseline (1989) were used to calculate BMI according to the equation of kg/m^2. MAC and CC were measured. Population-specific cut-points were used to define low or high anthropometric values. The present analysis used the higher threshold values of the anthropometric cut-points in the Mini Nutritional Assessment Taiwan Version-II[(10)]. The cut-points were <21 kg/m^2 for low and ≥ 27 kg/m^2 for high BMI for both men and women, 23.5/22 cm (for men/women) for low MAC, and 30/27 cm (for men/women) for low CC. No cut-point was established for high extremities. Mortality data were taken from records maintained by SHLSET, and confirmed with records of the Universal Health Insurance Program, and the National Household Registration. Age, gender, smoking status and routine physical activity-adjusted four-year follow-up survival curves classified according to BMI, MAC and CC statuses for subjects aged 53-64, 65-74 and ≥75 years were shown in Fig. 2, 3 & 4, respectively. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the government-appointed representatives. Written informed consent was obtained from all subjects/patients.

Cox regression analyses were performed to evaluate the relative mortality risks of subjects with low or high BMI, or low MAC or CC adjusted for age, gender, smoking status and physical activity. Statistical significance for all analyses was evaluated at $\alpha = 0.05$.

Results

During the follow-up four-year period, 566 of 4191 respondents died. Mortality risk increased from 4% for 53-64-year old persons to 11% and 29% for persons aged 65-74 and ≥75 years, respectively. In all three age groups, persons with low BMI (<21 kg/m^2), low MAC (<23.5/22 cm for men/women) or low CC (<30/27 cm for men/women) had higher mortality risk than persons with normal BMI (21-27 kg/m^2) or circumferences (Table 2). Persons with excessive BMI (≥27 kg/m^2) had higher risk in near-old (53-64 years) persons but lower risk in older (≥65 years) persons compared to persons with normal BMI.

Cox regression analysis showed that underweight (<21 kg/m^2) significantly increased follow-up mortality risk in all three age ranges but the risk was greater (HR=2.79) (p<0.001) for 53-64-year old persons than for older persons (HR=1.54 for 65-74 years old & HR=1.38 for ≥75-year old persons, both p<0.01) (Fig. 2). Excessive weight (≥27 kg/m^2) appeared to increase mortality risk in 53-64-year old persons, but reduce risk in older (≥65 years) persons, but all these changes were not statistically significant (All $p>0.05$).

Small MAC increased follow-up mortality risk in 53-64-year old and 65-74-year old persons, but not in ≥75-year old elderly using normal MAC as the reference (Fig. 3). Small CC increased follow-up mortality risk in elderly persons (65-74 & ≥75 years old) (both p<0.001) using normal CC as the reference; but the increase in 53-64-year old persons was not significant (Fig. 4).

Discussion

Results of the present study suggest that all three anthropometrics (BMI, MAC and CC) have long-term mortality risk-predicting values in older adults, but their relative effectiveness varies and is dependent on age. Low BMI (<21 kg/m^2) is more effective in predicting mortality risk in near-old (53-64-year old) persons than 65-74- or ≥75-year old elderly. Low MAC predicts increased mortality risk in 53-64- and 65-74-year old persons but not in ≥75-year old elderly. Low CC predicts increased follow-up mortality risk in 65-75-year and ≥75-year old elderly but not in younger near-old (53-64 years old) persons.

In near-old (53-64 years) persons, the utility of MAC and CC in predicting follow-up mortality risk is limited because only a small proportion (1.9%) of persons has reduced circumferences. Therefore, although these indicators have high specificity they have poor sensitivity. In 65-74-year old persons, MAC and especially CC are more effective in predicting mortality risk than BMI. In ≥75-year old persons, CC is the most effective, followed by BMI; MAC is not effective.

In the present study, high BMI (≥27 kg/m^2) only suggests increased risk in younger (53-64-year old) persons and reduced risk in older (65-74-year and ≥75-year old) persons, none of these effects reached statistical significance.

The ability of BMI to predict follow-up mortality risk has been observed in numerous studies[11-18]. Most studies indicate a J- or U-shaped association but the thresholds for low and excessive BMI vary among populations or studies. The thresholds generally fall within <BMI 20-23 for underweight and >BMI 25-30 for excessive weight, depending on the age range of study subjects and statistical conditions applied.

Some recent large scale studies have indicated a positive association of mortality risk with excessive BMI and an inverse association with low BMI. In a recent study involving over half a million 50-71-year old persons in the US, Adams et al.[19] observed that the risk of death was associated with both overweight (BMI25-30) and obesity (>BMI 30) among men and women when the analysis was restricted to healthy people who had never smoked. The Prospective Studies Collaboration[20] which analyzed 57 prospective studies involving 900,000 adults suggested that mortality was lowest at about 22.5–25 kg/m²; above or below this range, the overall mortality increases. In a national cohort involving 64,731 men and 19,011 women, Freeman et al.[21] observed that among younger/middle-aged (<55 years) never-smoking women, risk rose as BMI increased above 21.0 kg/m^2 whereas in older women, risk increased beginning at a higher BMI (>25.0 kg/m^2). Among younger men who never smoked, risk began to rise above 23.0 kg/m^2, whereas in older men, risk did not begin to increase until exceeding 30.0 kg/m^2. In Eastern populations, Tamakoshi et al.[22] observed that all-cause mortality risk is lowest and fairly consistent between BMI 20 and 30 in both older Japanese men and women 65-79 years of age. Jee et al.[23] indicated a lowest all-cause mortality risk of BMI 23-25 for Koreans 30-90 years old. On the other hand, the study by Auyeung et al.[24] indicated that BMI is effective in predicting all-cause mortality risk for underweight (<BMI 21) males but not females, and not for excessive weight in Chinese 65 years of age or older in Hong Kong. Taken together, these results suggest that BMI has mortality risk predictive ability but the thresholds for underweight and excessive weight vary among populations and are age dependent.

Circumferences of the extremities, especially MAC and CC have been found to be very useful for evaluating health and nutritional statuses of elderly persons[25,26] and these measures can provide valuable information on muscle-related disability, physical function and mortality risk[27,28]. Larger circumference of the extremities, especially CC has been observed to have protective health effects[29,30]. An inverse association between upper arm circumference and mortality has previously been observed in males[14] and females[15] of the NHANES (National Health and Nutrition Examination Survey) I and II. An inverse association between upper arm circumference and mortality risk has also been observed in 61-79-year men in the British Regional Heart Study[31] after adjusting for multiple indicators of ill health. Because MAC does not decline until later stage of body functional decline, it has been suggested that it is not as useful in serving as an indicator of nutritional status in younger old as it is in older individuals[32,33]. In the Canada Fitness Survey (CFS), arm, thigh, and calf circumferences were significantly protective in men while arm and thigh circumferences were protective in women[34]. It was postulated that these inverse associations between circumferences of the extremities and health risk may be owed to a greater accumulation of subcutaneous lean-body mass, adipose tissue, or a combination of these factors in the periphery.

Thus, it is clear that in addition to BMI, MAC and CC have good and in many cases, better follow-up mortality-risk predicting abilities. However, despite of these well recognized observations, the predictive ability of these extremities has rarely been directly compared[34]. especially examining the relative effectiveness during various stages of the elderly life. To our knowledge, the current study is the first time to observe an age-dependent relationship of the relative effectiveness of the three measures in predicting follow-up mortality in elderly persons.

Because these anthropometrics reflect body fatness, physical functioning and health statuses and can predict follow-up mortality-risk, these indicators can play an important role in health or nutrition assessment scales. Most health or nutritional assessment tools include some indicators of body weight such as BMI or recent weight changes[7] and only few such as the Mini Nutritional Assessment include MAC and CC in addition to BMI[35].

Results of the present study lead us to wonder whether BMI should be the preferred or nearly the only anthropometrics included in most of the geriatric assessment tools and whether the same threshold should be applied across the populations. As we have observed, MAC and especially CC are better predictors of follow-up mortality risk than BMI in the elderly. Consideration should be given to include these indicators in the assessment tools in order to achieve the most accurate results. In frail elderly there are clear advantages in using CC and/or MAC rather than BMI. Compared to weight and height (for computing BMI), CC and MAC are easier and more accessible and time-efficient to measure in frail or disabled individuals.

For persons who are non-ambulatory or have difficulty standing erectly, BMI can be calculated from estimates of stature and weight. Stature can be estimated from tibia length or knee height and weight can be estimated from knee height and MAC.[36-38] However, these estimations require ethnic/race, age and gender-specific equations and measurements of knee height and tibia length may require special devices. The process is generally more involved than measuring MAC or CC and the quality of estimates may sometimes be questionable.[36] Thus, for the purposes of this study computation of BMI using these estimates is not favored.

There are strengths and limitations in the present study. A major strength is that the data set is from a prospective cohort study involving a relatively large nationally representative sample, thus results should have good generalizability. However, the sample size is not yet large enough for certain sections such as individuals >30 kg/m^2. In the survey, weight and height are self-reports. Self-reported height and weight are generally known to be accurate[10] but some errors or deviations from true values are unavoidable. CC and MAC data were measured but no follow-up data were available therefore we cannot evaluate the effect of changes in body weight or circumferences over time. We adjusted age, gender, smoking status and routine physical activity to minimize the potential confounding effects by these factors but we cannot rule out other confounding factors.

Results of the present study indicate that three frequently used anthropometric parameters, BMI, MAC and CC, are effective in predicting follow-up-mortality risk of older adults but their ability are age-dependent. Among the three indicators, CC has the strongest predictive ability in elderly over 65 years old and MAC also has good predictive ability in 65-74-year elderly. BMI is most effective in younger (53-64 years) persons. Considering that CC and MAC are more accessible and easier to measure than BMI, especially in frail or ill persons, effort should be made to increase the use of these indicators in many of the geriatric health or nutritional assessment tools.

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(Legends for figures):

Fig. 1. Sampling process of the Survey of Health and Living Status of the Elderly in Taiwan (SHLSET)

Fig. 2. Age, gender and smoking status-adjusted four-year follow-up survival curves stratified by body mass index (BMI) status (<21 kg/m^2, line A " ——— "; 21-27 kg/m^2, line B " ------ "; and ≥27 kg/m^2, line C " –·–·–· ") and age range (53-64 y, Panel A; 65-74 y, Panel B; and ≥75 y, Panel C). Cox regression analysis (adjusted for age, gender, exercise and smoking status) showed that underweight (<21 kg/m^2) was associated with higher follow-up mortality risk. HR (adjusted odds ratio) and 95% CI (confidence interval) were 2.79 (1.58-4.95) for 53-64 y, 1.54 (1.12-2.13) for 65-74 y & 1.38 (1.10-1.74) for elderly ≥75 y (all p<0.01), using elderly normal weight (21-27 kg/m^2) as the reference. Excessive weight (≥27 kg/m^2) was not significant associated with mortality risk. The HR & (95% CI) were 1.45 (0.70-2.98) for 53-64 y, 0.58 (0.31-1.08) for 65-74 y & 0.78 (0.50-1.21) for ≥75 y elderly, (all p>0.05) using subjects with desirable weight (21-27 kg/m^2) as the reference.

Fig. 3. Age, gender and smoking status-adjusted four-year follow-up survival curves stratified by size of mid-arm circumference (MAC) (<23.5cm for men/22cm for women (line A " ——— ") or ≥23.5/22 cm (line B " ------ ") and age range (53-64 y, Panel A; 65-74 y, Panel B; and ≥75 y, Panel C). Cox regression analysis (adjusted for age, gender, exercise and smoking status) showed that small MAC (<23.5/22 cm) was associated with higher follow-up mortality risk. HR (adjusted odds ratio) and 95% CI (confidence interval) were 3.39 (1.22-9.45) (p<0.05) for 53-64

y, 2.19 (1.37-3.50) (*p*<0.001) for 65-74 y and 1.31 (0.93-1.84) (*p*>0.05) for ≥75 y elderly using subjects with MAC ≥23.5/22 cm as the reference.

Fig. 4. Age, gender and smoking status-adjusted four-year follow-up survival curves stratified by size of calf circumference (CC) (<30cm for men/27cm for women (line A "——— ") or ≥30/27cm (line B "------ ") and age range (53-64 y, Panel A; 65-74 y, Panel B; and ≥75 y, Panel C). Cox regression analysis (adjusted for age, gender, exercise and smoking status) showed that small calf circumference (<30/27 cm) was associated with higher follow-up mortality risk. HR (adjusted odds ratio) and 95% CI (confidence interval) were 2.64 (0.82-8.46) (p>0.05) for 53-64 y, 2.59 (1.66-4.06) (p<0.001) for 65-74 y & 1.98 (1.52-2.58) (*p*<0.001) for ≥75 y elderly using subjects with calf circumference ≥30/27cm as the reference.

Table 1. Baseline characteristics of 4191 men and women

Parameter	n (%)	Mean ± SD
Gender		
Men	2228 (53.2)	
Women	1963 (46.8)	
Age (y)		68.75 ± 9.13
53-64	1490 (35.6)	
65-74	1536 (36.6)	
≥75	1165 (27.8)	
Formal education (y)		
<6	1934 (46.2)	
≥6	2256 (53.8)	
Current smoker		
Yes	1022 (24.4)	
No	3169 (75.6)	
Routine exercise		
≤ 2 times/wk	2005 (47.8)	
≥ 3 times/wk	2185 (52.2)	
Height (cm)		
Men		164.7 ± 6.3
Women		153.3 ± 6.2
Weight (kg)		

Men	63.1 ± 9.7
Women	55.4 ± 9.6
Body mass index (kg/m^2)	
Men	23.2 ± 3.1
Women	23.6 ± 3.7
Mid-arm circumference (cm)	
Men	28.4 ± 3.5
Women	28.0 ± 4.0
Calf-circumference (cm)	
Men	34.7 ± 3.7
Women	32.9 ± 3.9

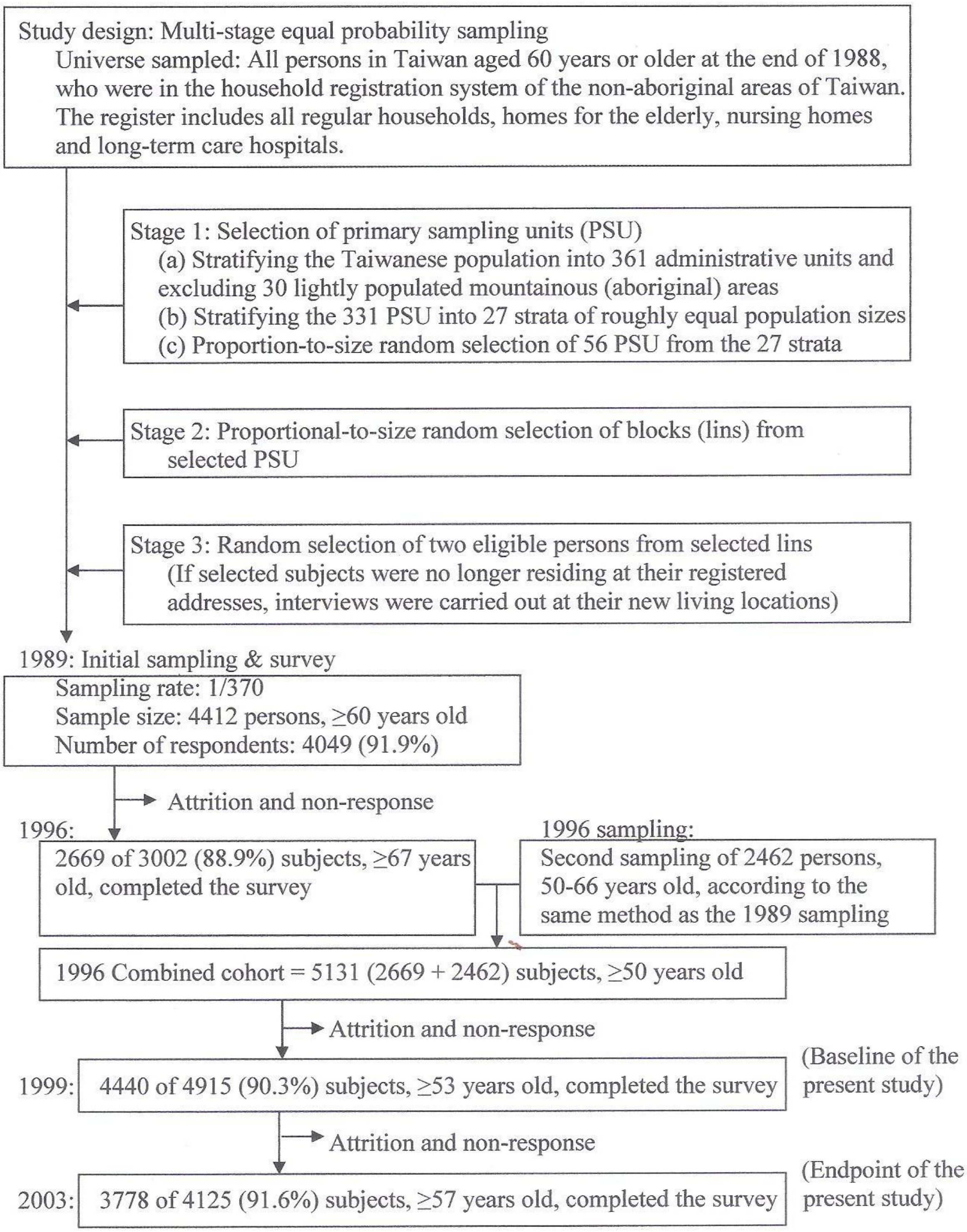
Table 2. The follow-up four-year mortality records (No. of deaths/No. of subjects) in older Taiwanese classified by age and anthropometric statuses (N = 4191)

Parameter	53-64 y	65-74 y	≥75 y
All subjects	59/1490 (4.0)[a]	172/1536 (11.2)	335/1165 (28.8)
Body mass index			
<21 kg/m^2	20/256 (7.8)	59/352 (16.8)	147/405 (36.3)
21-27 kg/m^2	29/990 (2.9)	102/982 (10.4)	165/636 (25.9)
≥27 kg/m^2	10/244 (4.1)	11/202 (5.4)	23/124 (18.5)
Mid-arm circumference			
<23.5/22[b] cm	4/29 (13.8)	21/77 (27.3)	40/97 (41.2)
≥23.5/22 cm	55/1461 (3.8)	151/1459 (10.3)	295/1068 (27.6)
Calf circumference			
<30/27[b] cm	3/29 (10.3)	23/76 (30.3)	72/143 (50.3)
≥30/27 cm	56/1461 (3.8)	149/1460 (10.2)	263/1022 (25.7)

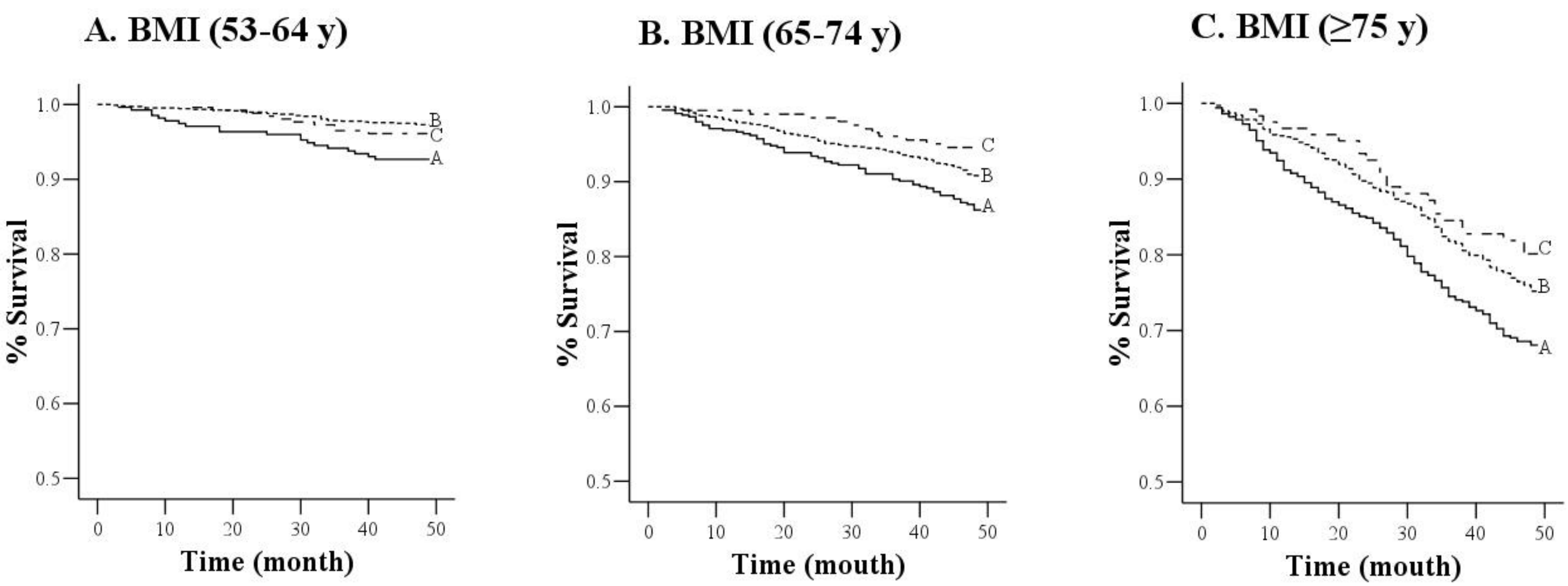
[a]Number of deaths in four years/total number of subjects in group at baseline.

[b]Cut-off values for men/women.

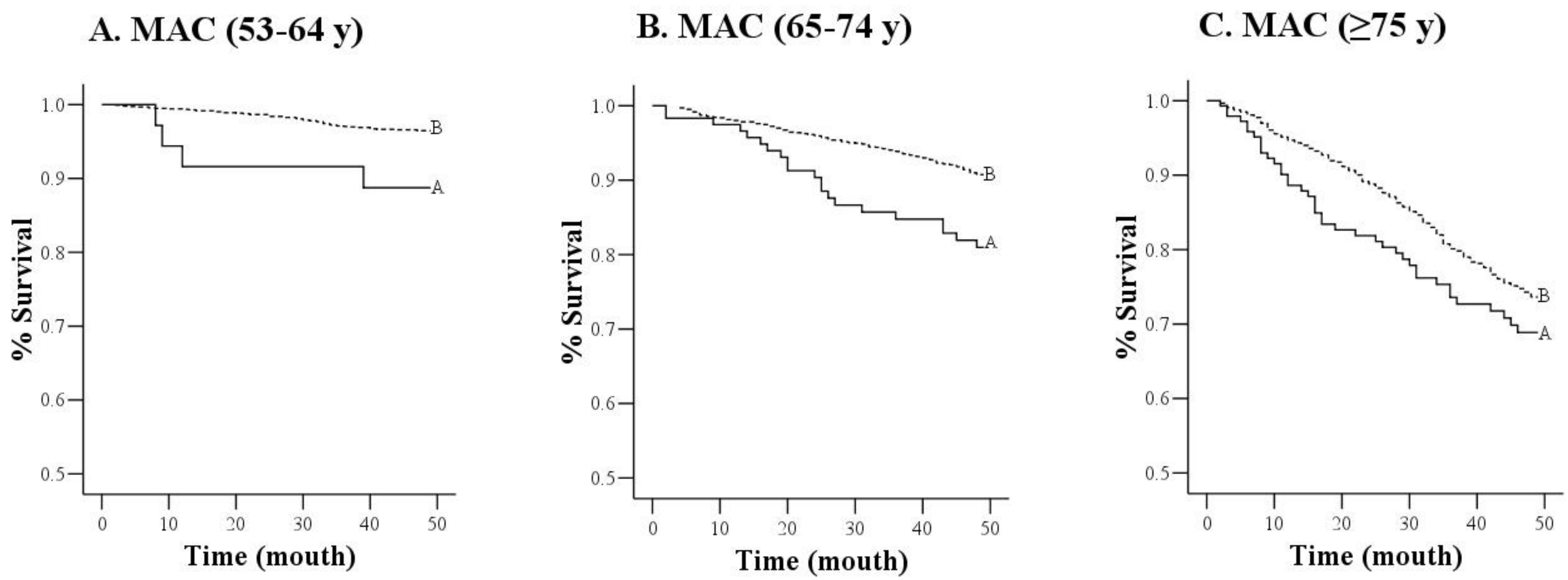
(Fig. 1)


Study design: Multi-stage equal probability sampling
Universe sampled: All persons in Taiwan aged 60 years or older at the end of 1988, who were in the household registration system of the non-aboriginal areas of Taiwan. The register includes all regular households, homes for the elderly, nursing homes and long-term care hospitals.
Stage 1: Selection of primary sampling units (PSU)
(a) Stratifying the Taiwanese population into 361 administrative units and excluding 30 lightly populated mountainous (aboriginal) areas
(b) Stratifying the 331 PSU into 27 strata of roughly equal population sizes
(c) Proportion-to-size random selection of 56 PSU from the 27 strata
Stage 2: Proportional-to-size random selection of blocks (lins) from selected PSU
Stage 3: Random selection of two eligible persons from selected lins
(If selected subjects were no longer residing at their registered addresses, interviews were carried out at their new living locations)
1989: Initial sampling & survey
Sampling rate: 1/370
Sample size: 4412 persons, ≥60 years old
Number of respondents: 4049 (91.9%)
Attrition and non-response
1996:
2669 of 3002 (88.9%) subjects, ≥67 years old, completed the survey
1996 sampling:
Second sampling of 2462 persons, 50-66 years old, according to the same method as the 1989 sampling
1996 Combined cohort = 5131 (2669 + 2462) subjects, ≥50 years old
Attrition and non-response
1999:
4440 of 4915 (90.3%) subjects, ≥53 years old, completed the survey
(Baseline of the present study)
Attrition and non-response
2003:
3778 of 4125 (91.6%) subjects, ≥57 years old, completed the survey
(Endpoint of the present study)

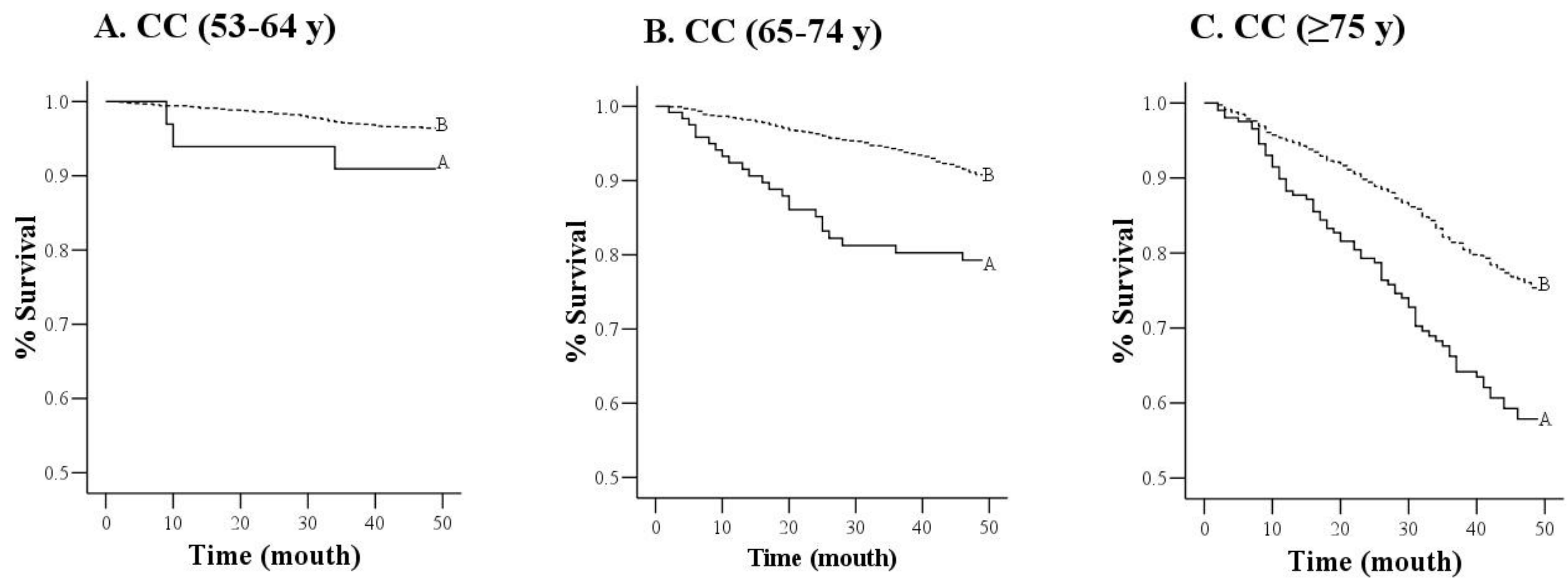
(Fig. 2)


A. BMI (53-64 y)
B. BMI (65-74 y)
C. BMI (≥75 y)
% Survival
1.0
0.9
0.8
0.7
0.6
0.5
0
10
20
30
40
50
A
B
C
Time (month)
Time (mouth)
Time (mouth)

(Fig. 3)


A. MAC (53-64 y)
B. MAC (65-74 y)
C. MAC (≥75 y)
% Survival
Time (mouth)
1.0
0.9
0.8
0.7
0.6
0.5
0
10
20
30
40
50
A
B

(Fig. 4)


A. CC (53-64 y)
B. CC (65-74 y)
C. CC (≥75 y)
% Survival
Time (mouth)
1.0
0.9
0.8
0.7
0.6
0.5
0
10
20
30
40
50
A
B