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Corrected arm muscle area: An independent predictor of long-term mortality amongst community-dwelling older adults?

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Abbreviated title: Corrected Arm Muscle Area and Mortality

ABSTRACT

Objective: Older people are at risk of undernutrition because of a number of physiological conditions and lifestyle factors. The purpose of this study was to explore the predictive relationship of the corrected arm muscle area (CAMA) with 8-year mortality in a representative sample of older Australians.

Design: Prospective cohort study: The Australian Longitudinal Study of Ageing.

Setting: Community.

Participants: One thousand three hundred ninety-six participants aged 70 years and older.

Measurements: Trained observers measured baseline weight, height, mid upper arm circumference, and triceps skinfold thickness using standard techniques. Body mass index (BMI) and CAMA were calculated. Baseline BMI and CAMA measurements were categorized according to cut-off values proposed by Garrow et al. and Friedman et al. respectively. Subsequent analyses were undertaken using Cox proportional hazards regression.

Results: After adjustment for potential confounders (baseline age, gender, marital status, smoking, self rated health, ability to conduct activities of daily living, co-morbidity, cognition performance and presence of depression), those older Australians with a low CAMA ($\leq$21.4cm^2 for men and $\leq$21.6cm^2 for women) had an increased risk of mortality at 8 year follow-up (hazard ratio = 1.94, 95% confidence interval = 1.25-3.00, P = .003). There was no increased risk in 8-year mortality identified for those with a high or a low BMI.

Conclusion: CAMA is a useful assessment of undernutrition in older adults that has better prognostic value than BMI in predicting death in older, community-living Australians.

Keywords: mortality; older; anthropometry; CAMA; Cox proportional hazards regression

INTRODUCTION

Poor nutritional health is directly related to adverse health outcomes, including quality of life,[1,2] disability[3,4] and mortality.[5-9] There is also evidence to suggest that correcting nutritional deficits in older adults improves prognosis and life expectancy.[10-12]

Anthropometric measurements are assuming greater importance in the clinical assessment of nutritional health. Although ideally the interpretation of anthropometry should be confirmed by assessment of dietary intake and biochemical parameters,[13] this is not always possible. The simple, cheap and potentially reliable nature of anthropometry means that body weight, girths and skinfold measures are often being used in isolation to describe nutritional health both in clinical practice and research settings.

There are some obstacles to the application and interpretation of anthropometry in older adults. Many older adults are kyphotic or have some form of disability that prevents the accurate measurement of stature and therefore calculation of body mass index (BMI) is prone to error. There is also the issue of fluid status in older adults with body weight potentially confounded by dehydration and edema or ascites. Furthermore, measurement of body weight is difficult in older adults who are immobile or extremely ill.

Corrected arm muscle area (CAMA) has been developed to account for the problem of arm muscle area overestimating actual arm muscle area (adjusted for bone) by 15-20%. CAMA is a useful addition to other anthropometric techniques, such as height and weight, as an indicator of nutritional health in older adults.[14] CAMA is calculated using a standard formula that takes into account the mid-upper arm circumference and the triceps skinfold (TSF) thickness of the right arm.[14] Friedman et al. first proposed CAMA as a way to identify older individuals at risk of undernutrition.[15] Values signifying nutritional risk were determined by Friedman et al. after review and analysis of three international data-sets[16-18] and correspond to the fifth percentile for British subjects aged 70-99.[16] Friedman et al. first used these values ($\leq$16.0cm^2 and $\leq$16.9cm^2 for men and women respectively) and then conducted further analysis to show that even CAMA approaching these values ($\leq 21.4cm^2$ and $\leq 21.6cm^2$ for men and women respectively) had prognostic value.[15] These CAMA values have since been evaluated in older adults from both non-institutionalised[5,19-21] and institutionalised settings[22,23] and shown to be predictive of short-term (3-46 months) mortality and other important clinical outcomes.

The purpose of this study was to explore CAMA as an independent predictor of 8-year mortality in a community sample of older adults participating in the Australian Longitudinal Study of Ageing (ALSA).

METHODS

Study participants

The study sample was taken from the ALSA, a comprehensive, epidemiological study aimed at identifying factors that contribute to and predict the health and social well-being of older Australians. The study is described in detail elsewhere.[24] In short, the ALSA enrolled a random selection of older adults from the South Australian State Electoral Database in 1992/93. All potential participants were residing in the Adelaide Statistical Division and the rate at which respondents were drawn into the sample varied by their sex, age and region of residence. In addition to the specified persons, spouses (aged 65 and older) and other household members aged 70 and older were included. One thousand seven hundred and ninety-nine community-dwelling participants aged 70 and older were interviewed; 1396 consented to a subsequent clinical assessment. Every 12 months, the ALSA investigators have documented official deaths for the study participants using data from government births, death, and marriage records. For study participants who died out of state or overseas, the ALSA investigators contacted relatives to confirm date of death. Ethical approval was obtained from Flinders Clinical Investigation (Ethics) Committee. Written informed consent was obtained from each participant.

Anthropometry

Trained observers took anthropometric measurements in each participant's home using the methods described by the World Health Organization.[25] Measurements of height (to the nearest 0.1cm) were made using a portable stadiometer and body weight (to the nearest 0.1kg) using portable scales. Subjects were measured in light clothing without shoes. All subjects were able to stand erect in the correct position for height to be measured. BMI (weight (kg) / height $(m)^2$) was calculated and individuals categorized as desirable weight (20-25kg/m^2), underweight (<20kg/m^2), overweight (>25-30kg/m^2) and obese (>30kg/m^2).[26] Measurement of TSF thickness (to the nearest 0.2mm) was made using Harpenden skinfold calipers [range: 0.00 to 50.00mm; minimum graduation: 0.20mm; accuracy: 99.00%] and mid upper arm circumference (MUAC) (to the nearest 0.1cm) using a flexible steel measuring tape, on the right side of the participant's body unless affected by disability or disease. Arm muscle circumference ($AMC = MUAC_{(cm)} - 0.3142 x TSF_{(mm)}$) and corrected arm muscle area (CAMA) were calculated using standard formulae[14]:

$$CAMA\ cm^2 = AMC_{(cm)2} / 4\pi - 10 \text{ (men)}$$

$$CAMA\ cm^2 = AMC_{(cm)2} / 4\pi - 6.5 \text{ (women)}$$

The categorization of CAMA used to define poor nutritional health were established in a sample of older adults in New Zealand, with $21.4cm^2$ or less for men and $21.6cm^2$ or less for women considered "near malnourished".[15]

Potential confounding variables

The following baseline variables were considered potential confounders in the statistical analyses: gender (male; female), age group (70-74; 75-79; 80-84; ≥85], marital status [married/partner; widowed; never married/divorced/single], smoking status [current; ex-smoker; never smoked], self-rated health [poor-fair; good; very good-excellent], activities of daily living (ADLs),[27,28] the 10 most prevalent co-morbid conditions [range 0-10; including any cancer, arthritis, heart attack, heart condition, hypertension, ulcers, diabetes, respiratory disease, hernia, stroke], presence of depression using the Centre Epidemiological Studies Depression scale (range 0-48),[29] and cognitive performance using a subset of questions from the Mini-Mental State Examination (no impairment ≥17; impaired <17).[30]

Statistical Analyses

A Cox proportional hazard regression model using time to death from the initial interview as the endpoint was used to analyse the relationships between corrected arm muscle area, body mass index and mortality. We used 8 years after the first interview as the censoring date. If a participant was still alive at the censoring date, the time in days from the date of their baseline interview was taken to be 2,921. If the participant had died between the baseline interview and the censoring date, the number of days that he or she had survived after the baseline interview was calculated. Results are presented for all participants.

All analyses were conducted using the SPSS statistical package version 9.0 (SPSS Inc, Chicago, IL).

RESULTS

Table 1 shows baseline descriptive statistics for age, CAMA, BMI and mortality. The men were older, had higher CAMA values and a higher death rate over the 8-year study than the women. At baseline, male participants were more likely to be current or ex-smokers (P<.001) and more likely to be married or living with a partner (P<.001). Female participants were more likely than male participants to have cognitive impairment (P=.015) and greater depressive symptomatology (P=.040). There was no significant gender difference in self rated health, ADL status, or morbid load.

Table 2 shows the Cox proportional hazard regression model for CAMA and 8-year mortality and BMI and 8-year mortality after adjusting for the potential confounders. A low CAMA (≤21.4cm^2 for men and ≤21.6cm^2 for women) showed an increased risk of death at 8 years. Neither a low BMI (<20kg/m^2), a BMI suggestive of overweight (>25-30kg/m^2) nor a BMI indicative of obesity (>30kg/m^2) showed any significant influence on risk of death at 8-year follow-up.

Figures 1 and 2 show the cumulative survival curve over the 8 years for men and women, respectively, with a low CAMA (near malnourished) and a CAMA suggesting nonmalnourished as defined by Friedman.[15] Men with a CAMA of 21.4cm^2 or less and women with a CAMA of 21.6cm^2 or less had a lower survival rate at the 8-year follow-up.

DISCUSSION

We examined the relationship of baseline CAMA and 8-year mortality in 1,396 older community-dwelling Australians. After controlling for a large range of potential confounding variables, including presence of depression, cognitive performance, and co-morbidity, a low CAMA (men $\leq$21.4cm^2 and women $\leq$21.6cm^2) almost doubled the risk of death at 8-year follow-up.

Other studies have investigated CAMA and mortality in older adults. A study based in a New Zealand hospital[15] followed 201 admissions aged 65 and older for up to 90 days and found that men with CAMA of 16.1 to 21.4cm^2 and women with CAMA of 17.3 to 21.6cm^2 had a significantly greater risk of mortality than did those with a higher CAMA. More recently, in a Switzerland Geriatric Assessment Unit, it was found that an abnormally low CAMA (lower then the fifth percentile of American age- and gender-matched reference data[31]) is strongly associated with increased mortality at 4.5-year follow-up.[23] CAMA was evaluated in older community-dwelling adults in a study of older adults in New Zealand[5] following 825 people aged 70 and older for 40-46 months and also showed increased risk of death. The authors of these studies have shown that a low CAMA is associated with an increased risk of mortality and, despite limited adjustments for potential confounders, have, among others,[20-23,32,33] recommended using CAMA to diagnose undernutrition in older people, because it is a simple, quick, and economical approach in hospital and community settings. Our study provides further support for the use of CAMA in older community-living Australians over a longer time period and after adjustment for many potential confounders.

Clinicians underutilize CAMA in the nutritional assessment of older adults. Traditionally, BMI has been targeted in the assessment of nutritional health and effect on mortality, especially amongst younger adults, but results of large studies of middle-aged and older adults investigating the relationship between BMI and mortality however have been inconsistent,[7, 34-41] and the utility of BMI and the traditional cut-off (20-25kg/m^2 (desirable)) in older adults is perhaps_questionable.

Issues such as kyphosis, osteoporosis, and disability can influence the reliability of height measurement in older adults, and body weight can reflect fluid status rather than actual weight. It is worthy to note that, even though all participants in this study were able to stand in the correct position to be measured, many may have experienced some degree of "shrinkage" or vertebral collapse, and thus the calculated BMI may have been overestimated. Consideration of the changes in body composition that occur with advancing age suggest that BMI and the cutoff used to determine "health risk" are likely to be quite different in older adults. In our analyses using the traditional cutoff points (<20kg/m^2, 20-25kg/m^2, >25-30kg/m^2, >30kg/m^2)[26] BMI had no predictive value in terms of 8-year mortality. Different cutoff points for "desirable" and "overweight" have been proposed for older individuals, and use of these cutoff points may produce differing results,[42,43] but, in this study, even at the highest BMI category (>30kg/m^2) there was no increased risk of mortality. We suggest that CAMA may be a more practical and suitable index for use in the nutritional assessment of older adults. CAMA is inexpensive (Cost of a pair of skinfold calipers ($US 215) and a steel measuring tape is equivalent to the cost of scales and stadiometer) and simple, can be measured in all patients regardless of ambulation and is not significantly altered by fluid status. Although calculation of CAMA requires a more complex set of equations than does the calculation of BMI, future development of gender specific nomograms could improve the clinical utility of this index. The present study provides evidence to support that a low CAMA is an independent predictor of 8-year mortality.

There are limitations to the research reported here. The ALSA included a large number of clinical and non-clinical variables to allow suitable adjustments to be accounted for in the regression model, but, because of the extensive protocol, it may have excluded some of the most ill people, and therefore may not be a true representation of all older Australians living in the community. Men were significantly older than women, which was probably connected with the higher mortality rate seen in male participants at 8-year follow-up.[44] The criteria used to define undernutrition in our study are based on reference ranges suggested by Friedman et al.[15] following an international comparison of anthropometric reference datasets for those aged 55 to 99. Because of the small number of participants in our sample fitting the criteria of severe wasting (≤16.0cm^2 for men; ≤16.9cm^2 for women) that is highly predictive of poor health outcomes,[15] we evaluated the prognostic significance of a higher CAMA, suggested by Friedman to represent "near malnourished" below which individuals showed a higher risk of 90-day mortality than those categorized as nonmalnourished.[15]

Despite the limitations of this study, we conclude that a low CAMA independently predicts long-term mortality in older community-living Australians. The ease of measuring CAMA suggests that it could be an extremely useful tool for nutritional assessment of older adults. Further research is required to investigate the prognostic value of CAMA in different settings and the effect of intensive nutrition intervention in the improvement of CAMA.

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REFERENCES

1. Ponzer S, Tidermark J, Brismar K et al. Nutritional status, insulin-like growth factor-1 and quality of life in elderly women with hip fractures. Clin Nutr, 1999; 18(4):241-246.
2. Larsson J, Akerlind I, Permerth J et al. The relation between nutritional state and quality of life in surgical patients. Eur J Surg, 1994; 160:329-334.
3. LaCroix AZ, Guralnik JM, Berkman LF et al. Maintaining Mobility in Late Life. Am J Epidemiol, 1993; 137(8):858-869.
4. Launer L, Harris T, Rumpel C et al. Body mass index, weight change, and risk of mobility disability in middle-aged and older women: The epidemiologic follow-up study of NHANES I. J Am Med Assoc, 1994; 271(14):1093-1098.
5. Campbell AJ, Spears GFS, Brown JS et al. Anthropometric measurements as predictors of mortality in a community population aged 70 years and over. Age Ageing, 1990; 19:131-135.
6. Matilla K, Haavisto M, Rajala S. Body mass index and mortality in the elderly. Br Med J, 1986; 292:867-868.
7. Harris T, Cook EF, Garrison R et al. Body Mass Index and Mortality Among Nonsmoking Older Persons. J Am Med Assoc, 1988; 259(10):1520-1524.
8. Calle EE, Thun MJ, Petrelli JM et al. Body-mass index and mortality in a prospective cohort of US adults. N Eng J Med, 1999; 341(15):1097-1105.
9. Sullivan D.H, Walls RC, Lipschitz DA. Protein-energy undernutrition and the risk of mortality within 1 y of hospital discharge in a select population of geriatric rehabilitation patients. Am J Clin Nutr, 1991; 53(3):599-605.
10. Efthimiou J, Fleming J, Gomes C, Spiro SG. The effect of supplementary oral nutrition in poorly nourished patients with chronic obstructive pulmonary disease. Am Rev Respir Dis, 1988; 137: 1075-1082.
11. Delmi M, Rapin CH, Bengoa JM et al. Dietary supplementation in elderly patients with fractured neck of the femur. Lancet, 1990; 335:1013-1016.

12.Larsson J, Unosson M, Ek AC, Nilsson L, Thorsland S, Bjurulf P. Effect of dietary supplementation on nutritional status and clinical outcome in 501 geriatric patients – a randomized study. Clin Nutr, 1990; 9: 179-184.

13. Gibson R. Principles of nutritional assessment. 1990, Oxford: University Press.

14. Heymsfield S, McManus C, Smith J et al. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. Am J Clin Nutr, 1982; 36:680-690.

15. Friedman J, Campbell AJ, Caradoc-Davies, TH. Prospective trial of a new diagnostic criterion for severe wasting malnutrition in the elderly. Age Ageing, 1985; 14:149-154.

16. Department of Health and Social Security. Report on health and social subjects, 1979; H.M. Stationery Office: London.

17. Birbeck J. New Zealanders and their diet: A report to the National Heart Foundation of New Zealand on the National Diet Survey of 1977, 1983; University of Otago Press: Dunedin.

18. Frisancho AR. New norms of upper limb fat and muscle areas for assessment of nutritional status. Am J Clin Nutr, 1981; 34(11):2540-2545.

19. Friedman P. A prospective comparison of methods to identify lethal wasting malnutrition. Nutr Res, 1986; 6:139-146.

20. Prothro J, Rosenbloom, C. Body measurements of black and white elderly persons with emphasis on body composition. Gerontol, 1995; 41(1):22-38.

21. Woo J, Ho SC, Sham A et al. Influence of age, disease and disability on anthropometric indices in elderly chinese aged 70 years and above. Gerontol, 1995; 41:173-180.

22. Potter J, Klipstein K, Reilly JJ et al. The nutritional status and clinical course of acute admissions to a geriatric unit. Age Ageing, 1995; 24(2):131-136.

23. Muhlethaler R, Stack AE, Minder CE et al. The prognostic significance of protein and energy malnutrition in geriatric patients. Age Ageing, 1995; 24:193-197.

24. Andrews G, Cheok F, Carr S. The Australian Longitudinal Study of Ageing. Australian Journal of Ageing, 1989; 8:31-35.

25. World Health Organization. Use and interpretation of anthropometric indicators of nutritional status: Report of a WHO working group. Bulletin of the World Health Organization, 1986a;929-941.

26. Garrow J, Webster, J. Quetelet's Index (W/H^2) as a measure of fatness. Int J Obesity, 1985; 9: 147-153.

27. Katz S, Ford AB, Muskowitz RW et al. Studies of illness in the aged: the index of ADL, a standardized measure of biological and psychosocial function. J Am Med Assoc, 1963; 185:914-919.

28. Katz S, Downs TD, Cash, HR et al. Progress in development in the index of ADL. Gerontologist, 1970; 10:20-30.

29. Radloff L. The CES-D scale: a self-report depression scale for research in the general population. Appl Psychol Meas, 1977; 1:385-401.

30. Folstein M, Folstein S, McHugh P. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psych Res, 1975; 12(3):189-98.

31. Frisancho AR. New norms of upper limb fat and muscle areas for assessment of nutritional status. Am J Clin Nutr, 1981; 34(11): 2540-5.

32. Keller H. Malnutrition in institutionalised elderly: how and why? J Am Geriatr Soc, 1993; 41(11):1212-1218.

33. Lansey S, Waslein C, Mulvihill M et al. The Role of Anthropometry in the Assessment of Malnutrition in the Hospitalized Frail Elderly. Gerontol, 1993; 39:346-353.

34. Manson J, Willett W, Stampfer M et al. Body weight and mortality among women. N Engl J Med, 1995; 333:677-685.

35. Wannamethee G, Shaper A. Body weight and mortality in middle-aged British men: Impact on smoking. Br Med J, 1989; 299:1497-1502.

36. Lee I, Manson JE, Henneken CH et al. Body weight and mortality. A 27-year follow-up of middle-aged men. J Am Med Assoc, 1993; 270:2823-2828.

37. Stevens J, Keil JE, Rust PF et al. Body mass index and body girth as predictors of mortality in black and white women. Arch Intern Med, 1992; 152:1257-1262.

38. Wilcosky T, Hyde J, Anderson JJB et al. Obesity and mortality in the Lipid Research Clinics Program Follow-up Study. J Clin Epidemiol, 1990; 43:743-752.

39. Dorm J, Schisterman EF, Winkelstein W et al. Body mass index and mortality in a general population sample of men and women. Am J Epidemiol, 1997; 146:919-931.

40. Landi F, Zuccala G, Gambassi G et al. Body mass index and mortality among older people living in the community. J Am Geriatr Soc, 1999; 47:1072-1076.

41. Allison D, Gallagher D, Heo M et al. Body mass index and all-cause mortality among people age 70 and over: The Longitudinal Study of Aging. Int J Obesity, 1997; 21:424-431.

42. Wahlqvist M (Ed). Food and Nutrition: Australasia, Asia and the Pacific, 1997; Allen and Unwin, Sydney Australia.

43. National Health and Medical Research Council. Dietary Guidelines for Older Australians, 1999; Commonwealth of Australia, Canberra Australia.

44. Australian Institute of Health and Welfare. Older Australia at a glance – Second Edition. Commonwealth of Australia 1999; Catalogue number AGE12: Chapter 2.

Table 1: Age, Corrected Arm Muscle Area, Body Mass Index and 8 Year Mortality for Community-Dwelling Older Adults (N=1,96), by Gender: The Australian Longitudinal Study of Ageing, 1992-2000

	Women (n=624)	Men (n=772)	Total (n=1,96)
Age, years			
Mean	77.3‡	78.3‡	77.9
SD	5.6	5.8	5.7
Minimum	70	70	70
Maximum	103	96	103
CAMA (cm^2)*			
Mean	33.8S	40.9 S	37.8
SD	9.1	9.5	10.0
Minimum	11.5	13.9	11.5
Maximum	81.6	82.6	82.6
BMI (kg/m^2)†			
Mean	26.1	25.9	26.0
SD	4.5	3.5	4.0
Minimum	15.0	14.0	14.0
Maximum	48.0	41.0	48.0
8-y mortality, %	32.1 S	49.1 S	41.5

***** CAMA: Corrected Arm Muscle Area[14]
† BMI; Body Mass Index[25]
‡ P=0.002
S P<0.001

Table 2: Cox regression model for 8-year mortality using Corrected Arm Muscle Area and Body Mass Index and Adjusting for Potential Confounding Variables (n=1,396): The Australian Longitudinal Study of Ageing, 1992-2000

Variable	Hazard Ratio	95% CI	P-value
Gender			
Male*	1.00		
Female	0.59	0.48-0.73	<0.001
Age group			
70-74*	1.00		
75-79	1.63	1.24-2.14	<0.001
80-84	2.91	2.23-3.81	<0.001
85+	4.90	3.70-6.48	<0.001
Marital Status			
Married/Partner*	1.00		
Widowed	1.38	0.95-2.00	0.094
Never Married/Separated/Divorced	1.00	0.81-1.23	0.980
Self-rated health			
Excellent or Very Good*	1.00		
Good	1.44	1.14-1.82	0.002
Fair or Poor	1.94	1.52-2.48	<0.001
Smoking Status			
Never Smoker*	1.00		
Ex-smoker	1.21	0.98-1.49	0.081
Current Smoker	1.76	1.27-2.45	0.001
Co-morbid Conditions	1.14	1.06-1.22	<0.001

Presence of Depression[†]	1.01	1.00-1.02	0.117
Cognitive Performance[‡]			
MMSE ≥ 17[*]	1.00		
MMSE <17	1.43	1.15-1.77	0.001
Assistance required with Activities of Daily Living (ADL) [S]			
≤1 ADL[*]	1.00		
>1 ADL	1.13	0.89-1.44	0.324
CAMA (cm^2)			
>21.4 (male), >21.6 (female) [*]	1.00		
≤21.4 (male), ≤21.6 (female)	1.94	1.25-3.00	0.003
BMI (kg/m^2)			
20-25	1.00		
<20	1.36	0.94-1.99	0.106
>25-30	0.99	0.82-1.21	0.951
>30	1.13	0.86-1.49	0.388

* Reference category

[†] Presence of depression[27]

[‡] Cognitive performance[28]

[S] ADL: Generated using a series of questions from Katz et al.[40,41] Limitation defined as requiring help or experiencing difficulty in one or more activities of daily living.

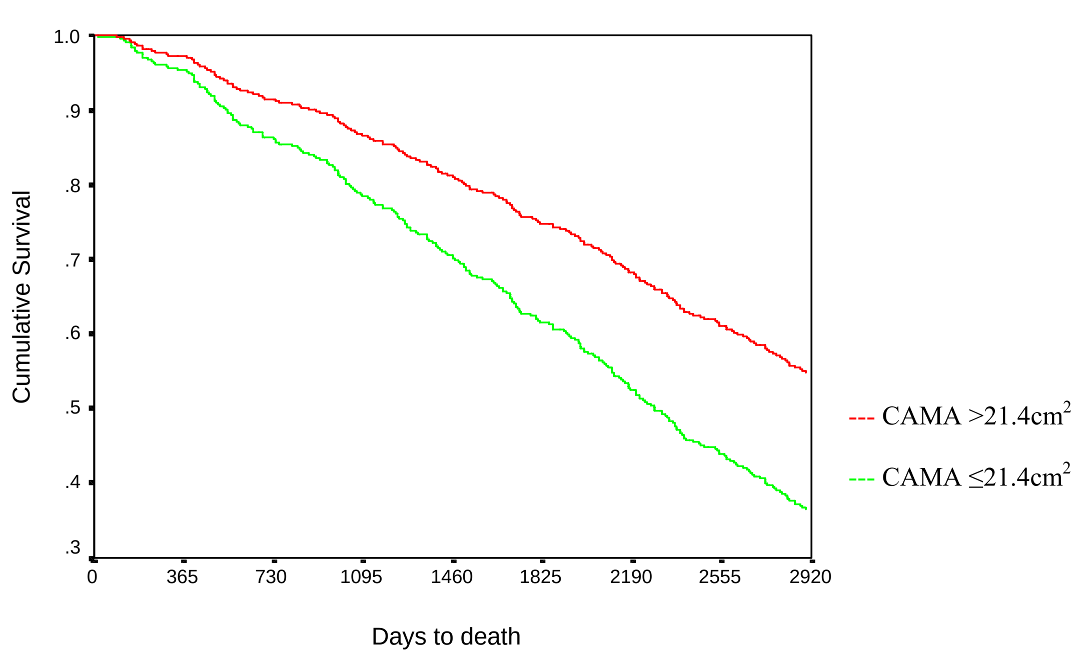

Figure 1. Corrected arm muscle area (CAMA) and cumulative survival over 8 years (adjusted for potential confounding variables) for the 772 men aged 70 and older: the Australian Longitudinal Study of Ageing.

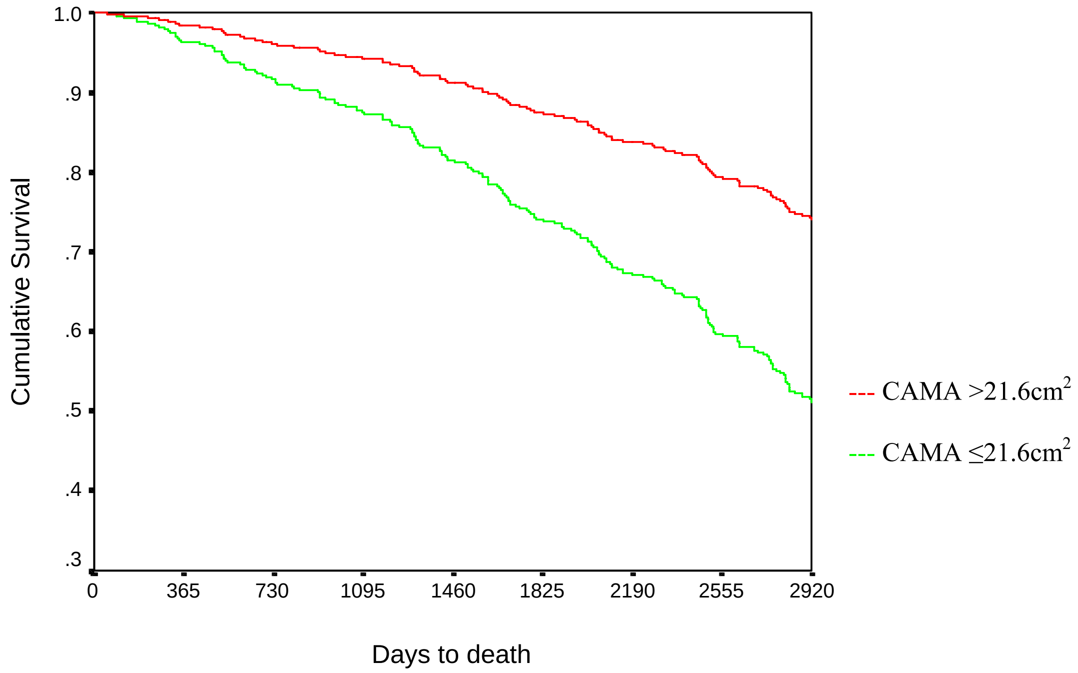

Figure 2. Corrected arm muscle area (CAMA) and cumulative survival over 8 years (adjusted for potential confounding variables) for 624 women aged 70 and older: the Australian Longitudinal Study of Ageing.