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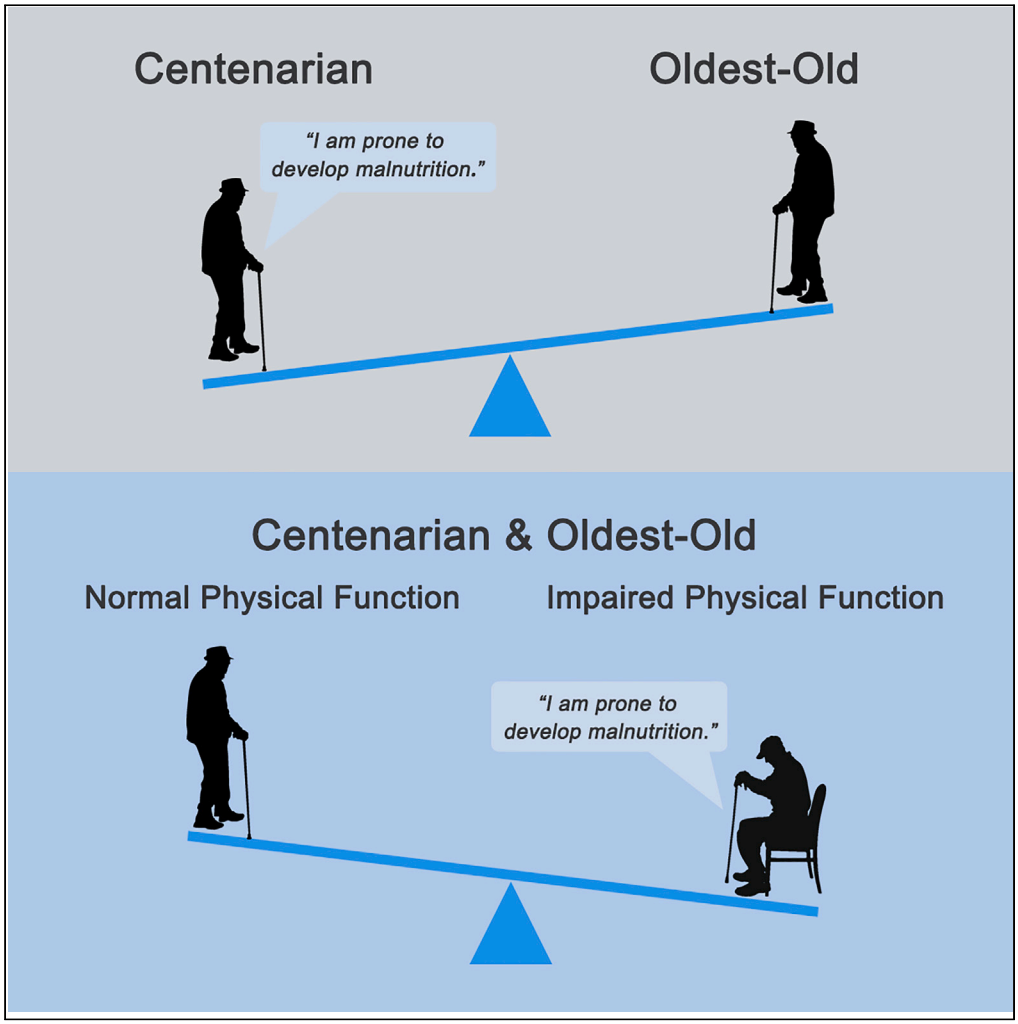


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## Highlights

We explored epidemiological characteristics and associated factors of malnutrition

Malnutrition risk and impaired physical function were prominent in centenarians

Physical function was independently associated with malnutrition in the elderly

Corresponding effective measures could be taken by us to promote healthy aging

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# Prevalence and correlates of malnutrition risk among Chinese centenarians and oldest-old adults

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## SUMMARY

**This study was to explore epidemiological characteristics of malnutrition and factors associated with malnutrition in centenarians and oldest-old adults, so as to provide a reference for family members and government departments to take effective measures and promote healthy aging. Median age of all 1,654 participants was 100 (85, 102) years old, and prevalence of high malnutrition risk was 65.54% in all participants. Proportion of high-malnutrition risk was higher, and proportion of normal physical function was lower, in centenarians than those in oldest-old adults ($p < 0.05$ for all). Univariate and multivariate Poisson regression analyses showed that normal physical function was negatively associated with malnutrition risk in all participants, centenarians, and oldest-old adults ($p < 0.05$ for all). In conclusion, proportion of centenarians at malnutrition risk was significantly higher than that of oldest-old adults, and the independent factor associated with malnutrition in people aged over 80 years was physical function.**

## INTRODUCTION

Population aging is a universal phenomenon, and it is more pronounced in China. According to the statistical bulletin of the People's Republic of China on National Economic and Social Development in 2019, the population over the age of 65 years in China had reached 176 million by the end of 2019, accounting for 12.6% of the total population[1] and far exceeding the world standard of 7.0%.[2] The Global Strategy and Action Plan for Aging and Health for 2016–2020, formulated by the World Health Organization and its member states, points out that the research on healthy aging should be promoted and the network of age-friendly cities should be strengthened.[3] The Healthy China 2030 Plan also points out that the elderly health service system should be built to solve health problems and explore healthy aging of the elderly. Due to the decrease of physiological functions, the elderly will inevitably face many challenges. Among them, malnutrition in the elderly has been considered as a universal health problem. A meta-analysis[4] showed that in Europe, about 28% of population over the 65 years old was at high-malnutrition risk, and proportion of citizens over the 80 years old was 14.9%–40.6% in different countries. Malnutrition may have extensive impacts on the physical and cognitive function of the elderly and will increase the incidence of chronic diseases and all-cause mortality of the elderly.[5–8]

The factors causing malnutrition in the elderly are very complex, and one key factor that promoting its occurrence is aging itself. At present, studies have shown that age is one of the factors associated with malnutrition in the elderly.[9] The old are at higher risk of developing malnutrition as they get older. Patients are more likely to lose weight due to chronic consumption. Norman and colleagues[10] believed that malnutrition was mainly manifested as increased protein and fat decomposition, and muscle mass and function loss. In addition, decline of psychological and cognitive functions, as well as social, economic and working conditions, may also increase the incidence of malnutrition in the elderly.[11] As a special group of the elderly, centenarians have experienced a long-period old age and a particularly prominent problem of Geriatric syndromes.[12] However, due to biological limitations, the oldest-old (80–99 years old) are relatively few, while centenarians are extremely rare, in the whole population. There were few studies on the epidemiology and factors associated with malnutrition in the oldest-old and centenarian populations. Based on the China Hainan Centenarian Cohort Study (CHCCS) and China Hainan Oldest-old Cohort Study (CHOCS) databases, the current study selected the oldest-old aged 80–99 years and the centenarians as research objects to explore epidemiological characteristics of malnutrition and factors associated with malnutrition in these two populations, so as to provide a

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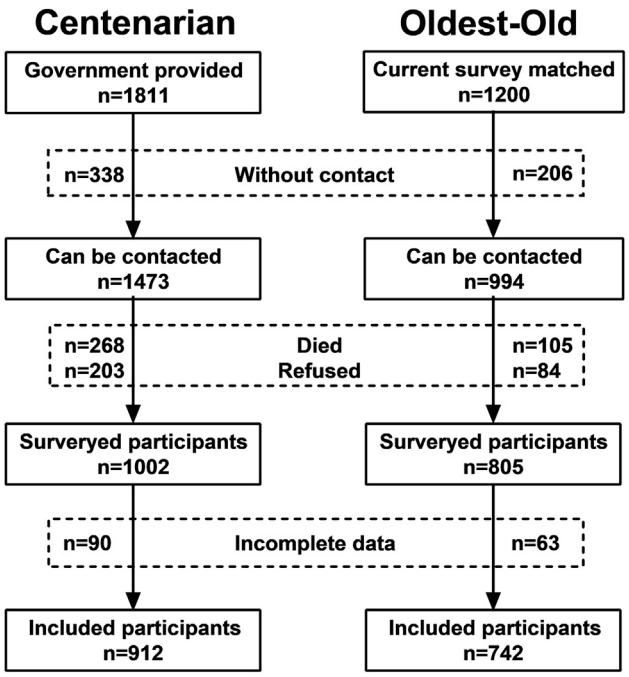


**Figure 1. Flow chart for participant selection**

reference for family members and government departments to take effective measures and promote healthy aging.

## RESULTS

### Participants

As shown in Figure 1, the Civil Affairs Department of Hainan Province provided 1,811 centenarians, of whom 1,473 can be contacted. At the end of the survey, 268 died and 203 refused to visit, so 1,002 centenarians participated in the survey. There were 90 centenarians excluded from the study due to a lack of relevant data; therefore, a total of 912 centenarians were included in the study. Accordingly, 805 oldest-old adults participated in the survey. After excluding 63 people with incomplete data, a total of 742 oldest-old adults were included in this study.

### Characteristic comparison between centenarians and oldest-old adults

Median age of all participants was 100 (85, 102) years old, among which, median age of 912 centenarians was 102 (101, 104) years old, and median age of 742 oldest-old adults was 84 (82, 88) years old. Among all participants, 72.73% were female, 88.63% were Han ethnicity, 84.89% were illiteracy, and 72.79% were single. Participants with smoking and drinking were 6.59% and 12.39%, respectively. Prevalence of hypertension and diabetes were 27.51% and 10.34%, respectively. Only 2.96% of the elderly were engaged in mental work before retirement. Proportion of normal physical function in all participants was 51.27%, among which, proportions of normal physical function in centenarians and oldest-old adults was 28.95% and 78.71%, respectively. Prevalence of high-malnutrition risk in all participants was 65.54%, among which, prevalence of high-malnutrition risk in centenarians and oldest-old adults was 85.96% and 40.43%, respectively.

As shown in Table 1 and Figure 2, proportions of males, educated, married, smoking, drinking, hypertension, diabetes, mental work and normal physical function, and levels of MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, DBP, hemoglobin, RBC, TP, albumin, ALT, AST, cholesterol, and triglyceride, were significantly lower, and proportion of high-malnutrition risk, and SBP and glucose levels were significantly higher, in centenarians than those in oldest-old adults ($p < 0.05$ for all).

**Table 1. Characteristic comparison between centenarians and oldest-old adults**

| Characteristics | Total (n = 1654) | Centenarian (n = 912) | Oldest-old (n = 742) | p value |
|---|---|---|---|---|
| Age(years) | 100(85, 102) | 102(101, 104) | 84(82, 88) | <0.001 |
| Gender[n(%)] | | | | <0.001 |
| Male | 451(27.27) | 158(17.32) | 293(39.49) | |
| Female | 1203(72.73) | 754(82.68) | 449(60.51) | |
| Ethnicity[n(%)] | | | | 0.107 |
| Han | 1466(88.63) | 798(87.50) | 668(90.03) | |
| Minority | 188(11.37) | 114(12.50) | 74(9.97) | |
| Education[n(%)] | | | | <0.001 |
| Illiteracy | 1404(84.89) | 838(91.89) | 566(76.28) | |
| Educated | 250(15.11) | 74(8.11) | 176(23.72) | |
| Marital status[n(%)] | | | | <0.001 |
| Married | 450(27.21) | 88(9.65) | 362(48.79) | |
| Single | 1204(72.79) | 824(90.35) | 380(51.21) | |
| Smoking[n(%)] | | | | <0.001 |
| Yes | 109(6.59) | 34(3.73) | 75(10.11) | |
| No | 1545(93.41) | 878(96.27) | 667(89.89) | |
| Drinking[n(%)] | | | | 0.004 |
| Yes | 205(12.39) | 94(10.31) | 111(14.96) | |
| No | 1449(87.61) | 818(89.69) | 631(85.04) | |
| Hypertension[n(%)] | | | | <0.001 |
| Yes | 455(27.51) | 218(23.90) | 237(31.94) | |
| No | 1199(72.49) | 694(76.10) | 505(68.06) | |
| Diabetes[n(%)] | | | | 0.005 |
| Yes | 171(10.34) | 77(8.44) | 94(12.67) | |
| No | 1483(89.66) | 835(91.56) | 648(87.33) | |
| Work type[n(%)] | | | | <0.001 |
| Mental work | 49(2.96) | 13(1.43) | 36(4.85) | |
| Moderate manual work | 978(59.13) | 499(54.71) | 479(64.56) | |
| Heavy manual work | 627(37.91) | 400(43.86) | 227(30.59) | |
| Physical function[n(%)] | | | | <0.001 |
| Impaired | 286(17.29) | 259(28.40) | 27(3.64) | |
| Mildly impaired | 520(31.44) | 389(42.65) | 131(17.65) | |
| Normal | 848(51.27) | 264(28.95) | 584(78.71) | |
| MMSE | 12(8, 15) | 12(6, 13) | 12(11, 19) | <0.001 |
| BMI(Kg/m$^2$) | 19.72(3.675) | 18.81(3.44) | 20.83(3.66) | <0.001 |
| Periumbilical fat thickness(cm) | 1.20(0.80, 1.50) | 1.10(0.70, 1.24) | 1.24(0.98, 1.70) | <0.001 |
| Waist circumference(cm) | 76(70, 83) | 75(69, 80) | 78(73, 86) | <0.001 |
| Hip circumference(cm) | 86(81, 92) | 84(80, 89) | 89.5(84, 95) | <0.001 |
| Calf circumference(cm) | 26(24, 29) | 25(23, 27) | 28(26, 31) | <0.001 |
| SBP(mmHg) | 150.87(24.491) | 152.56(24.58) | 148.79(24.23) | 0.002 |
| DBP(mmHg) | 77.85(13.259) | 75.90(13.10) | 80.25(13.07) | <0.001 |
| Hemoglobin(g/L) | 119.19(18.333) | 113.66(16.43) | 125.98(18.28) | <0.001 |
| RBC($\times 10^{12}$/L) | 4.20(0.656) | 4.03(0.62) | 4.41(0.64) | <0.001 |
| TP(g/L) | 70.38(5.930) | 69.19(6.15) | 71.85(5.30) | <0.001 |

(*Continued on next page*)

**Table 1. *Continued***

| Characteristics | Total (n = 1654) | Centenarian (n = 912) | Oldest-old (n = 742) | p value |
|---|---|---|---|---|
| Albumin(g/L) | 40.11(4.119) | 38.75(4.03) | 41.77(3.58) | <0.001 |
| Glucose(mmol/L) | 4.71(4.03, 5.46) | 4.88(4.22, 5.59) | 4.48(3.78, 5.25) | <0.001 |
| ALT(U/L) | 10.8(8.20, 14.10) | 9.60(7.40, 12.42) | 12.40(9.50, 16.10) | <0.001 |
| AST(U/L) | 21.65(18.50, 25.10) | 21.10(18.00, 24.40) | 22.30(19.18, 26.30) | <0.001 |
| Cholesterol(mmol/L) | 4.77(4.21, 5.45) | 4.67(4.08, 5.28) | 4.90(4.37, 5.70) | <0.001 |
| Triglyceride(mmol/L) | 1.07(0.82, 1.43) | 1.04(0.80, 1.35) | 1.10(0.84, 1.52) | <0.001 |
| Malnutrition risk[n(%)] | | | | <0.001 |
| High | 1084(65.54) | 784(85.96) | 300(40.43) | |
| Low | 570(34.46) | 128(14.04) | 442(59.57) | |

ALT: alanine transaminase; AST: aspartate aminotransferase; BMI: body mass index; DBP: diastolic blood pressure; MMSE: mini-mental state examination; RBC: red blood cell; SBP: systolic blood pressure; TP: total protein. Values are expressed as mean (standard deviation) or median (quartile spacing) or number (percentage). p value between groups: Student t test (continuous quantitative data conforming to normal distribution), Mann-Whitney U test (continuous quantitative data not conforming to non-normal distribution) and Pearson Chi-square test or Fisher exact test for categorical enumeration data.

### Characteristic comparison of all participants according to malnutrition risk

For all participants, the low-malnutrition risk group was significantly lower than the high-malnutrition risk group in age and proportions of females, illiteracy and single ($p < 0.05$ for all; Table 2). Proportions of smoking, drinking, mental work and normal physical function, and levels of MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, ALT, cholesterol, and triglyceride, were significantly higher in the low -malnutrition risk group than those in the high-malnutrition risk group ($p < 0.05$ for all).

### Characteristic comparison of centenarians according to malnutrition risk

As shown in Table S1, proportions of drinking and normal physical function, and levels of BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, and RBC, were significantly higher in the low malnutrition risk group of centenarians than those in the high malnutrition risk group of centenarians ($p < 0.05$ for all).

### Characteristic comparison of oldest-old adults according to malnutrition risk

As shown in Table S2, the low-malnutrition risk group of oldest-old adults was significantly lower than the high-malnutrition risk group of oldest-old adults in proportion of Han ethnicity ($p < 0.05$ for all). Proportion of normal physical function, and levels of BMI, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, ALT, and triglyceride, were significantly higher in the low-malnutrition risk group of oldest-old adults than those in the high-malnutrition risk group of oldest-old adults ($p < 0.05$ for all).

### Univariate and multivariate analyses of characteristics and malnutrition risk in all participants

Univariate Poisson regression analysis of all participants showed that malnutrition risk was significantly correlated with age, gender, education, marital status, smoking, drinking, mental work, normal physical function, MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, ALT, cholesterol, and triglyceride ($p < 0.05$ for all; Table 3). Multivariate Poisson regression analysis showed that age was positively associated with malnutrition risk, whereas normal physical function and BMI were negatively associated with malnutrition risk in all participants ($p < 0.05$ for all).

### Univariate and multivariate analyses of characteristics and malnutrition risk in centenarians

As shown in Table 4, univariate Poisson regression analysis of centenarians showed that drinking, heavy manual work, normal physical function, MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, and triglyceride were significantly correlated with malnutrition risk ($p < 0.05$ for all). Multivariate Poisson regression analysis showed that drinking

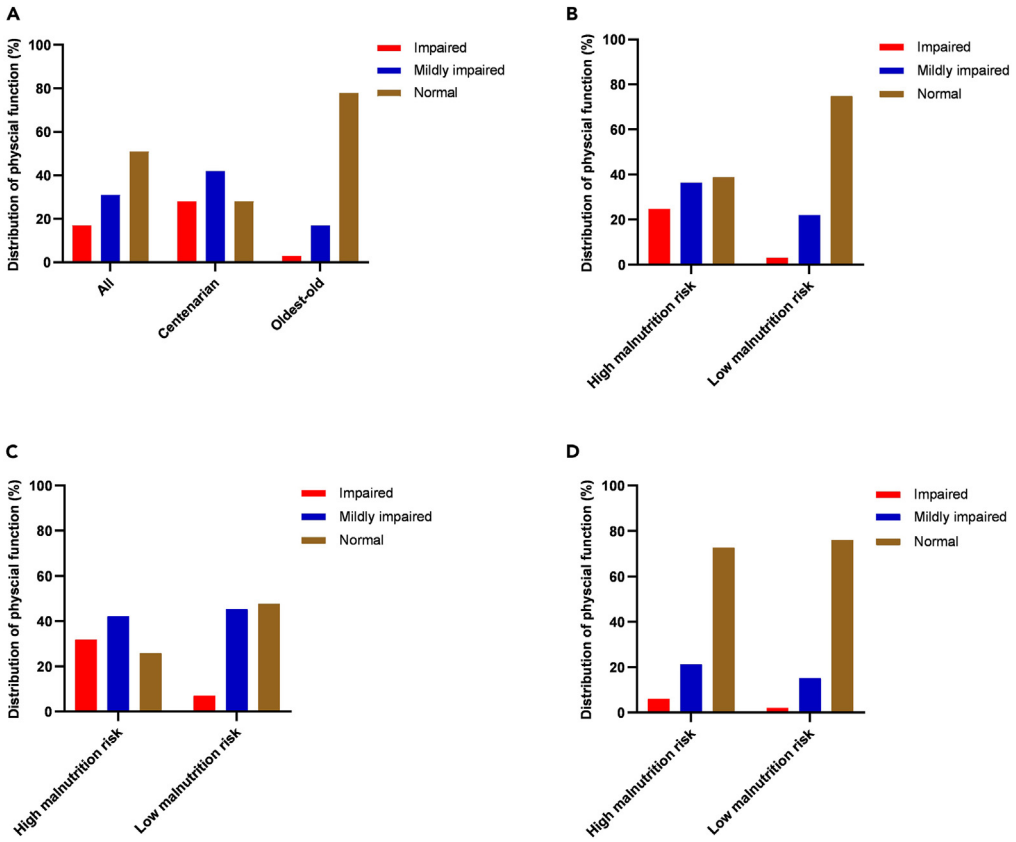


**Figure 2. Distribution of physical function**

Distribution of physical function in all participants (Panel A) and in all participants (Panel B), centenarians (Panel C) and oldest-old adults (Panel D) within different malnutrition risk groups.

and ALT was positively associated with malnutrition risk, while heavy manual work, normal physical function, and BMI were negatively associated with malnutrition risk in centenarians ($p < 0.05$ for all).

### Univariate and multivariate analyses of characteristics and malnutrition risk in oldest-old adults

As shown in Table 5, univariate Poisson regression analysis of oldest-old adults showed that Han ethnicity, normal physical function, BMI, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, ALT, and triglyceride were significantly correlated with malnutrition risk ($p < 0.05$ for all). Multivariate Poisson regression analysis showed that Han ethnicity, normal physical function, BMI, and albumin were negatively associated with malnutrition risk in oldest-old adults ($p < 0.05$ for all).

## DISCUSSION

### Prevalence of malnutrition risk

Prevalence of malnutrition varies significantly among different populations. A survey[13] based on multiple populations showed that prevalence of malnutrition was 0% in healthy young people, 0.5% in healthy middle-aged and elderly people, 6% in elderly outpatients, and 14% in middle-aged and elderly patients with acute diseases. Of course, there are institutional differences in malnutrition prevalence. A meta-analysis[14] showed that prevalence of malnutrition was 3.1% in the community, 6.0% in outpatients, 22.0% in inpatients, 17.5% in nursing homes, and 28.7% in long-term care receivers. Kaiser et al.[15] conducted an investigation on 4,507 elderly people (average age: 82.3 years old) in 12 countries and found that the overall prevalence of malnutrition was 22.8%, including 50.5% in the rehabilitation group, 38.7% in the inpatients, 13.8% in the family caregivers, and 5.8% in the community elderly, while proportion at high risk of

**Table 2. Characteristic comparison of all participants according to malnutrition risk**

| Characteristics | Low malnutrition risk (n = 570) | High malnutrition risk (n = 1084) | p value |
|---|---|---|---|
| Age(years) | 86(82, 96) | 101(92, 103) | <0.001 |
| Gender[n(%)] | | | <0.001 |
| Male | 202(35.44) | 249(22.97) | |
| Female | 368(64.56) | 835(77.03) | |
| Ethnicity[n(%)] | | | 0.843 |
| Han | 504(88.42) | 962(88.75) | |
| Minority | 66(11.58) | 122(11.25) | |
| Education[n(%)] | | | <0.001 |
| Illiteracy | 449(78.77) | 955(88.10) | |
| Educated | 121(21.23) | 129(11.90) | |
| Marital status[n(%)] | | | <0.001 |
| Married | 226(39.65) | 224(20.66) | |
| Single | 344(60.35) | 860(79.34) | |
| Smoking[n(%)] | | | 0.049 |
| Yes | 47(8.25) | 62(5.72) | |
| No | 523(91.75) | 1022(94.28) | |
| Drinking[n(%)] | | | 0.001 |
| Yes | 91(15.96) | 114(10.52) | |
| No | 479(84.04) | 970(89.48) | |
| Hypertension[n(%)] | | | 0.061 |
| Yes | 173(30.35) | 282(26.01) | |
| No | 397(69.65) | 802(73.99) | |
| Diabetes[n(%)] | | | 0.123 |
| Yes | 68(11.93) | 103(9.50) | |
| No | 502(88.07) | 981(90.50) | |
| Work type[n(%)] | | | 0.029 |
| Mental work | 24(4.21) | 25(2.31) | |
| Moderate manual work | 347(60.88) | 631(58.21) | |
| Heavy manual work | 199(34.91) | 428(39.48) | |
| Physical function[n(%)] | | | <0.001 |
| Impaired | 18(3.16) | 268(24.72) | |
| Mildly impaired | 125(21.93) | 395(36.44) | |
| Normal | 427(74.91) | 421(38.84) | |
| MMSE | 12(11, 18) | 12(8, 13) | <0.001 |
| BMI(Kg/$m^2$) | 22.73(2.866) | 18.13(2.997) | <0.001 |
| Periumbilical fat thickness(cm) | 1.24(0.94, 1.70) | 1.12(0.70, 1.40) | <0.001 |
| Waist circumference(cm) | 82(76, 88) | 74(68, 79) | <0.001 |
| Hip circumference(cm) | 92(86, 98) | 84(80, 89) | <0.001 |
| Calf circumference(cm) | 29(26, 32) | 25(23, 27) | <0.001 |
| SBP(mmHg) | 152.88(24.619) | 149.81(24.369) | 0.016 |
| DBP(mmHg) | 81.75(13.535) | 75.80(12.645) | <0.001 |
| Hemoglobin(g/L) | 126.87(17.624) | 115.15(17.390) | <0.001 |
| RBC(×$10^{12}$/L) | 4.44(0.646) | 4.08(0.625) | <0.001 |
| TP(g/L) | 71.66(5.294) | 69.71(6.1347) | <0.001 |

(*Continued on next page*)

**Table 2. *Continued***

| Characteristics | Low malnutrition risk (n = 570) | High malnutrition risk (n = 1084) | p value |
|---|---|---|---|
| Albumin(g/L) | 41.65(3.88) | 39.29(4.007) | <0.001 |
| Glucose(mmol/L) | 4.68(3.89, 5.39) | 4.73(4.08, 5.48) | 0.364 |
| ALT(U/L) | 12.41(9.20, 16.20) | 10.10(7.83, 13.08) | <0.001 |
| AST(U/L) | 21.90(18.90, 25.60) | 21.50(18.30, 25.00) | 0.083 |
| Cholesterol(mmol/L) | 4.87(4.36, 5.72) | 4.70(4.14, 5.35) | <0.001 |
| Triglyceride(mmol/L) | 1.16(0.87, 1.57) | 1.02(0.79, 1.35) | <0.001 |

ALT: alanine transaminase; AST: aspartate aminotransferase; BMI: body mass index; DBP: diastolic blood pressure; MMSE: mini-mental state examination; RBC: red blood cell; SBP: systolic blood pressure; TP: total protein. Values are expressed as mean (standard deviation) or median (quartile spacing) or number (percentage). p value between groups: Student t test (continuous quantitative data conforming to normal distribution), Mann-Whitney U test (continuous quantitative data not conforming to non-normal distribution) and Pearson Chi-square test or Fisher exact test for categorical enumeration data.

malnutrition was 46.2%. Wojzischke et al.[16] conducted a meta-analysis of 62 literature related to malnutrition and found that prevalence of malnutrition in the elderly was between 3% and 33%. The results of the current study showed that prevalence of malnutrition risk was 40.43% for the elderly aged between 80 and 99, while for the centenarians, this figure doubled to an astonishing 85.96%.

The bad news is that coronavirus disease 2019 (COVID-19) has created an unprecedented public health crisis on a global scale, particularly with the overwhelming prevalence of the Omicron (B.1.1.529) strain, which is more harmful to elderly patients with chronic diseases.[17,18] Previous study[19] on elderly hospitalized patients with COVID-19 in Wuhan showed that COVID-19 would increase malnutrition prevalence in elderly patients. Therefore, with the pandemic of COVID-19, it is particularly important to observe and improve nutritional status of the elderly. A possible reason for high prevalence of malnutrition in the elderly is that decreased chewing ability and digestive function; reduced chewing ability or limited function affect the intake, digestion, absorption, and utilization of nutrients in the elderly.[20] Secondly, with the decline of smell and taste functions, the reward system of central nervous system has a weakened perception of food, which will affect the appetite of the elderly.[21] A study of 4,417 elderly in the Japanese community[22] showed that prevalence of anorexia was 7.9% and 21.2% in non-fenced and fenced elderly, and an independent association was found between anorexia and weight loss in the elderly. Finally, other chronic diseases of the elderly also affect energy demand, intake, and metabolism of the organism.[23–25]

## BMI and malnutrition risk

BMI is an indicator of nutritional status.[26] Soini et al.[27] conducted a study on 272 elderly people aged 75–94 years, and the results showed that BMI was the most correlated with Mini-Nutritional Assessment (MNA). Previous meta-analysis[28] assessing the relationship between low BMI and clinical outcomes showed that intensive care unit mortality was significantly higher in patients with BMI $\leq$18.5 kg/m$^2$ than in the control group and hospital mortality was higher, with higher 5-year mortality. In the current study, there were significant differences in BMI between the two age groups and between the different malnutrition risk groups, and multivariate regression analyses also showed that low BMI was associated with increased prevalence of malnutrition risk within each group.

## Physical function and malnutrition risk

Physical and mental function may directly affect nutritional status of the elderly.[29,30] Malnutrition is closely related to physical function in the elderly, that is to say, impaired physical function will lead to malnutrition, and malnutrition will further aggravate the degree of impaired physical function, even leading to disability in severe cases of the elderly.[31] Malnutrition affects motor function of the elderly by affecting their ability to control lateral trunk during walking.[32] Goisser et al.[33] found that in elderly patients who were at risk of malnutrition before hip fracture, 68% of participants did not recover their physical function to the pre-fracture level after fracture recovery. Nishioka et al.[34] found that nutritional status in elderly patients with hip fracture was independently correlated with physical function during hospitalization and rehabilitation. Damage to physical function can also affect life expectancy in older adults. Another study[35] found that

**Table 3. Poisson regression analyses of characteristics and malnutrition risk in all participants**

| | Univariate | | Multivatiate | |
|---|---|---|---|---|
| Characteristics | RR(95% CI) | p value | RR(95% CI) | p value |
| Age | 1.070(1.062–1.076) | <0.001 | 1.034(1.026–1.043) | <0.001 |
| Gender | | | | |
| Male | 1.464(1.282–1.672) | <0.001 | 0.977(0.837–1.142) | 0.772 |
| Female | 1 | – | 1 | – |
| Ethnicity | | | | |
| Han | 0.979(0.796–1.204) | 0.843 | 1.120(0.943–1.330) | 0.195 |
| Minority | 1 | | 1 | |
| Education | | | | |
| Illiteracy | 1.513(1.304–1.757) | <0.001 | 1.063(0.914–1.236) | 0.428 |
| Educated | 1 | – | 1 | – |
| Marital status | | | | |
| Married | 0.569(0.501–0.647) | <0.001 | 0.955(0.841–1.084) | 0.477 |
| Single | 1 | – | 1 | – |
| Smoking | | | | |
| Yes | 1.274(1.015–1.597) | 0.036 | 0.986(0.820–1.185) | 0.878 |
| No | 1 | – | 1 | – |
| Drinking | | | | |
| Yes | 1.342(1.133–1.592) | 0.001 | 1.034(0.848–1.261) | 0.742 |
| No | 1 | – | 1 | – |
| Hypertension | | | | |
| Yes | 1.148(0.996–1.345) | 0.057 | 1.013(0.891–1.116) | 0.844 |
| No | 1 | – | 1 | – |
| Diabetes | | | | |
| Yes | 1.175(0.964–1.431) | 0.110 | 0.959(0.791–1.162) | 0.667 |
| No | 1 | – | 1 | – |
| Work type | | | | |
| Mental work | 1.543(1.134–2.100) | 0.006 | 1.205(0.908–1.597) | 0.196 |
| Moderate manual work | 1.118(0.969–1.289) | 0.125 | 1.056(0.929–1.200) | 0.410 |
| Heavy manual work | 1 | – | 1 | – |
| Physical function | | | | |
| Impaired | 8.000(5.102–12.500) | <0.001 | 4.367(2.890–6.623) | <0.001 |
| Mildly impaired | 2.096(1.773–2.475) | <0.001 | 1.287(1.101–1.504) | 0.001 |
| Normal | 1 | – | 1 | – |
| MMSE | 0.960(0.951–0.968) | <0.001 | 0.999(0.988–1.009) | 0.778 |
| BMI | 0.837(0.818–0.856) | <0.001 | 0.856(0.827–0.885) | <0.001 |
| Periumbilical fat thickness | 0.821(0.735–0.917) | <0.001 | 0.951(0.877–1.030) | 0.214 |
| Waist circumference | 0.950(0.944–0.955) | <0.001 | 0.995(0.985–1.006) | 0.385 |
| Hip circumference | 0.944(0.937–0.951) | <0.001 | 0.994(0.982–1.005) | 0.263 |
| Calf circumference | 0.951(0.934–0.963) | <0.001 | 1.008(0.998–1.017) | 0.113 |
| SBP | 0.997(0.994–0.999) | 0.015 | 1.001(0.999–1.004) | 0.337 |
| DBP | 0.979(0.976–0.983) | <0.001 | 1.001(0.995–1.006) | 0.838 |
| Hemoglobin | 0.978(0.975–0.980) | <0.001 | 1.001(0.997–1.005) | 0.690 |
| RBC | 0.592(0.544–0.644) | <0.001 | 0.959(0.847–1.085) | 0.500 |
| TP | 0.965(0.955–0.977) | <0.001 | 0.995(0.982–1.009) | 0.479 |

(*Continued on next page*)

**Table 3. *Continued***

| | Univariate | | Multivatiate | |
|---|---|---|---|---|
| Characteristics | RR(95% CI) | p value | RR(95% CI) | p value |
| Albumin | 0.905(0.889–0.921) | <0.001 | 1.021(1.001–1.041) | 0.036 |
| Glucose | 0.982(0.944–1.022) | 0.377 | 0.991(0.958–1.025) | 0.605 |
| ALT | 0.983(0.977–0.989) | <0.001 | 0.997(0.986–1.007) | 0.557 |
| AST | 0.997(0.991–1.004) | 0.422 | 1.005(0.993–1.016) | 0.425 |
| Cholesterol | 0.859(0.812–0.910) | <0.001 | 0.995(0.942–1.051) | 0.869 |
| Triglyceride | 0.788(0.734–0.846) | <0.001 | 0.987(0.900–1.082) | 0.777 |

ALT: alanine transaminase; AST: aspartate aminotransferase; BMI: body mass index; CI: confidence interval; DBP: diastolic blood pressure; MMSE: mini-mental state examination; RR: relative risk; RBC: red blood cell; SBP: systolic blood pressure; TP: total protein. Values are expressed as RR (95% CI). Poisson regression analysis was adjusted by age, gender, ethnicity, education, marital status, smoking, drinking, hypertension, diabetes, work type, physical function, MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, glucose, ALT, AST, cholesterol and triglyceride.

malnutrition risk was independently associated with 7-year mortality and physical function, and the combination of malnutrition and physical function predicted the lowest survival rate in 1,203 people over 60 years of age. More than 80% of the elderly in this study had impaired physical function, and the elderly with severely impaired physical function had a significantly increased malnutrition risk. Moreover, proportions of centenarians at risk malnutrition and with impaired physical function were significantly higher compared with the oldest-old adults. For the elderly over 85 years old, higher protein intake (>1.0 g/kg) is conducive to the improvement of disability.[36,37]

## Cognitive functions and malnutrition risk

Participants in different age groups and malnutrition risk groups had different scores of cognitive status, which was mainly manifested as significantly lower cognitive level in the older age group and the high-malnutrition risk group. This is consistent with the results of previous studies including the Japanese Centenarian study.[38–40] However, our multivariate regression analyses showed negative results. Different studies in different age groups have produced conflicting results. In a cross-sectional study[41] involving participants aged 65–84 years, nutritional status was identified as an independent risk factor for cognitive impairment. But studies from southern Brazil[42] showed that cognitive impairment was not associated with nutritional status in participants over 80 years of age.

## Social meaning of malnutrition prevention

Nutritional status of Chinese people has been greatly improved with the improvement of living standards. Overweight and obesity have become a hot topic among residents, while malnutrition is easy to be ignored by the public. Nutrition is the material basis for healthy survival of all living creatures. For the elderly in the descending stage, malnutrition will seriously affect their quality of life, leading to a high incidence of chronic diseases and a huge economic burden on society. In order to improve nutritional status and reduce malnutrition risk in the elderly, our government should strengthen nutrition propagation and health knowledge, promote pension industries and talent training, and improve service level of endowment institutions, such as providing a balanced diet, creating pleasant dining environmen,t and encouraging physical exercise activity.[43] Community medical staffs should regularly carry out family visits for the elderly, encourage the very elderly to do what they can, take proper exercise, and increase nutrition intake to slow down physical decline of the very elderly.[44] In order to actively respond to population aging, China's National Nutrition Plan (2017–2030) proposes to monitor nutritional status of the elderly and carry out ameliorative actions of nutrition, gradually covering more than 80% of the elderly in China, which is of great significance to promote the realization of healthy aging in China.

In conclusions, data from large sample based on CHCCS and CHOCS demonstrated that proportion of centenarians at malnutrition risk was significantly higher than that of oldest-old adults, and the independent factor associated with malnutrition in people aged over 80 years was physical function.

**Table 4. Poisson regression analyses of characteristics and malnutrition risk in centenarians**

| | Univariate | | Multivatiate | |
|---|---|---|---|---|
| Characteristics | RR(95% CI) | p value | RR(95% CI) | p value |
| Age | 1.003(0.950–1.058) | 0.921 | 0.996(0.946–1.050) | 0.887 |
| Gender | | | | |
| Male | 1.276(0.865–1.880) | 0.219 | 1.183(0.808–1.732) | 0.387 |
| Female | 1 | – | | 1 |
| Ethnicity | | | | |
| Han | 0.860(0.512–1.445) | 0.568 | 0.987(0.596–1.635) | 0.961 |
| Minority | 1 | – | | 1 |
| Education | | | | |
| Illiteracy | 1.280(0.760–2.155) | 0.354 | 1.362(0.825–2.247) | 0.227 |
| Educated | 1 | – | | 1 |
| Marital status | | | | |
| Married | 0.945(0.556–1.605) | 0.833 | 0.903(0.556–1.464) | 0.677 |
| Single | 1 | – | | 1 |
| Smoking | | | | |
| Yes | 1.271(0.603–2.674) | 0.529 | 1.007(0.492–2.061) | 0.985 |
| No | 1 | – | | 1 |
| Drinking | | | | |
| Yes | 1.805(1.203–2.710) | 0.004 | 1.802(1.206–2.688) | 0.004 |
| No | 1 | – | | 1 |
| Hypertension | | | | |
| Yes | 1.017(0.699–1.479) | 0.928 | 1.064(0.746–1.517) | 0.732 |
| No | 1 | – | | 1 |
| Diabetes | | | | |
| Yes | 0.919(0.504–1.678) | 0.783 | 0.681(0.284–1.634) | 0.390 |
| No | 1 | – | | 1 |
| Work type | | | | |
| Mental work | 2.375(0.327–14.493) | 0.421 | 2.941(0.441–19.608) | 0.266 |
| Moderate manual work | 1.393(1.009–1.923) | 0.044 | 1.466(1.079–1.996) | 0.015 |
| Heavy manual work | 1 | – | | 1 |
| Physical function | | | | |
| Impaired | 6.667(3.378–13.158) | <0.001 | 8.333(4.292–16.129) | <0.001 |
| Mildly impaired | 1.550(1.121–2.141) | 0.008 | 1.613(1.174–2.217) | 0.003 |
| Normal | 1 | – | | 1 |
| MMSE | 0.962(0.936–0.988) | 0.004 | 0.993(0.964–1.022) | 0.733 |
| BMI | 0.794(0.765–0.824) | <0.001 | 0.749(0.720–0.779) | <0.001 |
| Periumbilical fat thickness | 0.686(0.524–0.898) | 0.006 | 0.845(0.667–1.070) | 0.160 |
| Waist circumference | 0.958(0.943–0.973) | <0.001 | 1.003(0.983–1.024) | 0.750 |
| Hip circumference | 0.957(0.935–0.978) | <0.001 | 0.991(0.977–1.006) | 0.227 |
| Calf circumference | 0.941(0.895–0.988) | 0.014 | 0.990(0.945–1.038) | 0.679 |
| SBP | 0.992(0.985–0.999) | 0.025 | 1.006(0.999–1.014) | 0.096 |
| DBP | 0.982(0.971–0.993) | 0.002 | 1.002(0.986–1.018) | 0.830 |
| Hemoglobin | 0.983(0.973–0.994) | 0.002 | 1.008(0.995–1.021) | 0.216 |
| RBC | 0.689(0.534–0.889) | 0.004 | 0.867(0.637–1.181) | 0.365 |
| TP | 0.991(0.967–1.015) | 0.476 | 1.003(0.976–1.031) | 0.811 |

(*Continued on next page*)

**Table 4. *Continued***

| Characteristics | Univariate | | Multivatiate | |
|---|---|---|---|---|
| | RR(95% CI) | p value | RR(95% CI) | p value |
| Albumin | 0.982(0.940–1.027) | 0.433 | 0.962(0.916–1.011) | 0.125 |
| Glucose | 1.019(0.905–1.149) | 0.747 | 1.042(0.880–1.234) | 0.632 |
| ALT | 1.016(0.985–1.049) | 0.305 | 1.074(1.017–1.133) | 0.009 |
| AST | 1.008(0.988–1.029) | 0.422 | 1.020(0.983–1.058) | 0.290 |
| Cholesterol | 0.882(0.754–1.031) | 0.115 | 1.084(0.923–1.274) | 0.324 |
| Triglyceride | 0.789(0.654–0.953) | 0.014 | 0.945(0.732–1.221) | 0.667 |

ALT: alanine transaminase; AST: aspartate aminotransferase; BMI: body mass index; CI: confidence interval; DBP: diastolic blood pressure; MMSE: mini-mental state examination; RR: relative risk; RBC: red blood cell; SBP: systolic blood pressure; TP: total protein. Values are expressed as RR (95% CI). Poisson regression analysis was adjusted by age, gender, ethnicity, education, marital status, smoking, drinking, hypertension, diabetes, work type, physical function, MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, glucose, ALT, AST, cholesterol and triglyceride.

### Limitations of the study

Since this study was a cross-sectional study, causality cannot be determined in this study. In other words, malnutrition may have caused impaired physical function, or impaired physical function was responsible for malnutrition. Meanwhile, although this was a full sample survey of centenarians in Hainan Province, because centenarians are in the last years of their life, the family members of a small number of centenarians in poor condition will refuse to be visited, which will lead to more optimistic research results. The number of centenarians who died during a prolonged interview period also affected the results of the study. Moreover, the prevalence of high-malnutrition risk reported in this study was 65.54%. Relative risk (RR) may be overestimated when it exceeds 10%. Thus, Poisson regression analyses with robust variance were used all through this study.

## ETHICS APPROVAL

The current study received the approval from the Ethics Committee of Hainan Hospital of Chinese People's Liberation Army General Hospital (Sanya, Hainan; Number: 301HNLL-2016-01). Prior to the current study, written informed consents were required from all participants.

## STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

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**Table 5. Poisson regression analyses of characteristics and malnutrition risk in oldest-old adults**

| | Univariate | | Multivatiate | |
|---|---|---|---|---|
| Characteristics | RR(95% CI) | p value | RR(95% CI) | p value |
| Age | 1.008(0.994–1.022) | 0.254 | 0.991(0.979–1.003) | 0.147 |
| Gender | | | | |
| Male | 1.004(0.890–1.134) | 0.943 | 1.002(0.870–1.152) | 0.981 |
| Female | 1 | – | | 1 |
| Ethnicity | | | | |
| Han | 1.203(1.025–1.414) | 0.024 | 0.832(0.714–0.968) | 0.018 |
| Minority | 1 | – | | 1 |
| Education | | | | |
| Illiteracy | 1.040(0.907–1.192) | 0.573 | 0.967(0.841–1.112) | 0.640 |
| Educated | 1 | – | | 1 |
| Marital status | | | | |
| Married | 1.025(0.910–1.153) | 0.693 | 0.959(0.859–1.071) | 0.461 |
| Single | 1 | – | | 1 |
| Smoking | | | | |
| Yes | 0.909(0.733–1.127) | 0.368 | 1.008(0.841–1.208) | 0.933 |
| No | 1 | – | | 1 |
| Drinking | | | | |
| Yes | 1.052(0.897, 1.233) | 0.535 | 1.097(0.927–1.298) | 0.281 |
| No | 1 | – | | 1 |
| Hypertension | | | | |
| Yes | 1.009(0.889–1.144) | 0.895 | 1.021(0.910–1.147) | 0.717 |
| No | 1 | – | | 1 |
| Diabetes | | | | |
| Yes | 1.042(0.877–1.236) | 0.644 | 0.943(0.792–1.122) | 0.508 |
| No | 1 | – | | 1 |
| Work type | | | | |
| Mental work | 0.910(0.695–1.192) | 0.493 | 0.976(0.759–1.254) | 0.847 |
| Moderate manual work | 0.971(0.850–1.107) | 0.658 | 1.019(0.905–1.148) | 0.495 |
| Heavy manual work | 1 | – | | 1 |
| Physical function | | | | |
| Impaired | 1.880(1.099–3.215) | 0.021 | 2.141(1.420–3.226) | <0.001 |
| Mildly impaired | 1.225(1.025–1.464) | 0.026 | 1.166(0.998–1.362) | 0.053 |
| Normal | 1 | – | 1 | – |
| MMSE | 0.998(0.988–1.007) | 0.605 | 1.002(0.992–1.012) | 0.676 |
| BMI | 0.879(0.861–0.898) | <0.001 | 0.883(0.855–0.912) | <0.001 |
| Periumbilical fat thickness | 1.005(0.928–1.089) | 0.897 | 0.988(0.916–1.066) | 0.759 |
| Waist circumference | 0.962(0.957–0.968) | <0.001 | 1.006(0.996–1.016) | 0.258 |
| Hip circumference | 0.962(0.955–0.967) | <0.001 | 0.994(0.983–1.006) | 0.338 |
| Calf circumference | 0.973(0.962–0.984) | <0.001 | 1.007(0.998–1.016) | 0.117 |
| SBP | 0.995(0.993–0.998) | <0.001 | 1.001(0.998–1.004) | 0.436 |
| DBP | 0.988(0.984–0.992) | <0.001 | 1.000(0.995–1.005) | 0.987 |
| Hemoglobin | 0.990(0.986–0.993) | <0.001 | 0.999(0.996–1.003) | 0.781 |
| RBC | 0.779(0.717–0.846) | <0.001 | 1.040(0.936–1.155) | 0.470 |
| TP | 0.985(0.974–0.996) | 0.010 | 0.993(0.980–1.006) | 0.269 |

(*Continued on next page*)

**Table 5. *Continued***

| | Univariate | | Multivatiate | |
|---|---|---|---|---|
| Characteristics | RR(95% CI) | p value | RR(95% CI) | p value |
| Albumin | 0.950(0.934–0.965) | <0.001 | 1.028(1.009–1.047) | 0.003 |
| Glucose | 0.996(0.969–1.025) | 0.800 | 0.992(0.961–1.023) | 0.611 |
| ALT | 0.993(0.987–0.999) | 0.020 | 1.005(0.995–1.014) | 0.360 |
| AST | 1.005(0.998–1.011) | 0.199 | 0.998(0.987–1.009) | 0.730 |
| Cholesterol | 0.957(0.907–1.009) | 0.104 | 1.016(0.968–1.068) | 0.510 |
| Triglyceride | 0.863(0.814–0.915) | <0.001 | 0.992(0.915–1.077) | 0.853 |

ALT: alanine transaminase; AST: aspartate aminotransferase; BMI: body mass index; CI: confidence interval; DBP: diastolic blood pressure; MMSE: mini-mental state examination; RR: relative risk; RBC: red blood cell; SBP: systolic blood pressure; TP: total protein. Values are expressed as RR (95% CI). Poisson regression analysis was adjusted by age, gender, ethnicity, education, marital status, smoking, drinking, hypertension, diabetes, work type, physical function, MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, glucose, ALT, AST, cholesterol and triglyceride.

## SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.isci.2023.107076.

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## AUTHOR CONTRIBUTIONS

Conceptualization, S.H., D.Z., P.P., Y.Z., X.W., and S.F.; Investigation, S.H., Y.Z., X.W., and S.F.; Formal Analysis, D.Z., P.Z., and K.Y.; Writing – Original Draft, S.H., D.Z., K.Y., and X.W.; Writing – Review & Editing, P.P., P.Z., Y.Z., and S.F.

## DECLARATION OF INTERESTS

The authors declare no competing interests.

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## STAR★METHODS

### KEY RESOURCES TABLE

| REAGENT or RESOURCE | SOURCE | IDENTIFIER |
|---|---|---|
| Deposited data | | |
| EpiData (version 3.1) | EpiData Association | http://www.epidata.dk/ |
| Software and algorithms | | |
| GraphPad Prism (version 9.0.0) | GraphPad Software, LLC | https://www.graphpad.com |
| IBM SPSS Statistics (version 25.0.0) | IBM Corp. | https://www.ibm.com/products/spss-statistics |

### RESOURCE AVAILABILITY

#### Lead contact

Further information and requests for resources and reagents should be directed to and will be fulfilled by the lead contact, Shihui Fu (xiaoxiao0915@126.com).

#### Materials availability

No new unique reagents were developed by this study.

#### Data and code availability

All data reported in this paper will be shared by the lead contact author (Shihui Fu: xiaoxiao0915@126.com) upon request.

All information given under Deposited data in key resources table will be shared by the lead contact author (Shihui Fu: xiaoxiao0915@126.com) upon request.

This paper does not report original code.

Any additional information required to reanalyze the data reported in this paper is available from the lead contact (Shihui Fu: xiaoxiao0915@126.com) upon request

### EXPERIMENTAL MODEL AND SUBJECT DETAILS

The current study is derived from the previously reported CHCCS and CHOCS,[45,46] which are the largest databases of Chinese centenarian and oldest-old populations. The CHCCS is a cross-sectional study with a full sample based on a community population. This survey covered all centenarians in Hainan province, which has the highest density of centenarians in China. The CHOCS investigation group adopted stratified sampling method to select the most representative oldest-old adults in the same period and the same area as the control group, that is, the CHOCS study. The process and content of the investigation were the same for all participants, including questionnaire interview, physical examination, biological analyses and laboratory examination.

### METHOD DETAILS

#### Study design

CHCCS and CHOCS were implemented between June 2014 to December 2016. Based on the household registration information of centenarian and oldest-old populations provided by the Civil Affairs Department of Hainan Province, the investigators conducted a one-to-one household survey among centenarian (≥100 years old) and oldest-old (80–99 years old) populations in 18 cities of Hainan province, including questionnaire survey, physical examination and blood collection. The current study focused on the common problem of nutritional status of the extremely elderly based on the CHCCS and CHOCS database. The study was approved by the Ethics Committee of Hainan Hospital of Chinese People's Liberation Army General Hospital (Sanya, Hainan; Number: 301HNLL-2016-01). All participants signed informed consent before participating in the study.

### Participants

The inclusion criteria were as follows: 1) chronological age at least 80 years; 2) long-term residence in the survey area; 3) be conscious and able to complete questionnaire interview, physical examination and biological analyses; 4) willing to participate in the study and sign the informed consent form. Participants were excluded: 1) someone who was provided by government but was dead before survey, not successfully contacted or refused to participant; 2) someone who was deaf and unable to give an interview; 3) someone with incomplete baseline data and nutritional assessment data. There were 1,002 centenarians and 805 oldest-old adults enrolled by the end of the survey. A total of 912 centenarians and 742 oldest-old adults were included in this study after 90 centenarians and 63 oldest-old adults were excluded for incomplete data (Figure 1).

### Interview

Specifically designed questionnaire was filled by pre-trained local doctors and nurses who conducted one-to-one interviews with the elderly, and the information such as demographic data, personal medical history, lifestyle and habits, physical function and mental health were filled into questionnaire. The levels of education included: uneducated, private school, primary school, middle school, high school, university and above, and uneducated was categorized as illiteracy and the rest was categorized as educated. Jobs before retirement included: farmer, fisherman, herdsman, laborer, military/police, administrator, professional, sales and service personnel, etc. Farmer, fisherman and herdsman were categorized as heavy manual work. Laborer and military/police were categorized as moderate manual work. Administrator, professional, and sales and service personnel were categorized as mental work. Smoking was defined as the consumption of one or more cigarettes per day for at least 1 year. Drinking was defined as the consumption of 30 g or more alcohols per week for at least 1 year. The definition of hypertension and diabetes was obtained from professional guidelines.[47,48]

### Anthropometric measurements

Physical examination was conducted by experienced physicians at the time of the participants' morning calm. Body weight was measured in the fasting state using a stable scale. Since most participants have hunchback, height was measured by medical staff using a soft ruler starting from the top of the participants' head, along the back, spine, hip, popliteal fossa, and up to the heel. Periumbilical fat thickness, waist circumference, hip circumference and calf circumference were performed using the same length measuring tool with standardized methods.[49] Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured and documented twice in the resting state using an electronic blood pressure monitor (J732, Omron Corp., Japan), and the average of the measured data was used for subsequent analysis.

### Biochemical measurements

Fasting blood was collected by skilled nurses with more than 5 years of working experience, and analyzed by the Central Laboratory of our hospital within 4 h after collection. Analysis items included blood cytological components [hemoglobin and red blood cell (RBC)], and chemical components [total protein (TP), albumin, glucose, alanine aminotransferase (ALT), aspartate aminotransferase (AST), cholesterol and triglyceride].

### Malnutrition risk

Malnutrition risk screening was conducted using Mini Nutritional Assessment-Short Form (MNA-SF) designed specifically for the elderly by the European Society of Parenteral and Enteral Nutrition (ESPEN).[29] The scale investigated the participants' appetite, digestive problems, weight loss, activity ability, psychological trauma, psycho-psychological problems and body mass index (BMI) in the past 3 months. Each item of the survey was given 0–3 points, and added up to obtain the total score of MNA-SF. MNA-SF $\leq$11 was defined as high malnutrition risk, and MNA-SF > 11 was defined as low malnutrition risk.

### Physical function

Barthel scale was used to evaluate physical function represented by activities of daily life (ADL). Participants were given 0–15 points according to the completion of 10 items in daily life, including bathing, grooming, using the toilet, defecating, urinating, dressing, eating, climbing stairs, transferring beds and chairs, and walking on the ground. The total score was Barthel scale. Barthel scale $\geq$90 was classified as normal

physical function, ADL 60–89 was classified as mild impaired physical function, and ADL <60 was classified as impaired physical function.

### Cognitive function

Cognitive function of participants was evaluated by Mini-Mental State Examination (MMSE). Participants were evaluated for their ability to execute continuous command, reading comprehension, naming, composition, writing, memorization, time orientation, place orientation, memory, calculation and retelling, and given 0–5 points according to their completion. The total score of each item was added up to MMSE. The higher MMSE, the better cognition.

## QUANTIFICATION AND STATISTICAL ANALYSIS

### Quality control

Age verification: in addition to the birth date registered with the civil affairs department, investigators must also check the date provided by the participants and guardians. Unified process: questionnaire interviewer and physical examination personnel were pre-trained for 3 months. All survey procedure and forms were unified, and qualified measuring tools were adopted in this survey. Data Reliability: two colleagues with statistical background input the survey results into Epidata software, check the input data and deal with the outliers.

### Statistical analysis

Statistical analysis was performed using SPSS V25.0 software. Continuous quantitative data conforming to the normal distribution were displayed as mean (standard deviation), continuous quantitative data not conforming to the normal distribution were displayed as median (quartile spacing), and categorical enumeration data were displayed as number (percentage). For statistical comparison between groups, continuous quantitative data conforming to normal distribution were tested by Student t test, and those not conforming to normal distribution were tested by Mann-Whitney U test. For categorical enumeration data, Pearson Chi-square test was used. When expected value of cells was less than 5, Fisher exact test was used. Factors associated with malnutrition risk were analyzed by univariate and multivariate Poisson regression analyses. Poisson regression analyses were adjusted by age, gender, ethnicity, education, marital status, smoking, drinking, hypertension, diabetes, work type, physical function, MMSE, BMI, periumbilical fat thickness, waist circumference, hip circumference, calf circumference, SBP, DBP, hemoglobin, RBC, TP, albumin, glucose, ALT, AST, cholesterol and triglyceride. $p < 0.05$ was considered statistically significant.