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# The association between nutritional status and functional limitations among centenarians: a cross-sectional study

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## Abstract

**Background:** Although there have been studies on the association between nutritional status and functional limitations, there were few studies on Asian centenarians in community. Therefore, this study aims to identify associations between nutritional status and functional limitations among centenarians in China.

**Methods:** This cross-sectional study was conducted with the data from the China Hainan Centenarian Cohort Study. These data ultimately included basic characteristics, hematologic indicators, and chronic disease status for 1,002 centenarians. The nutritional status was evaluated using the Mini Nutritional Assessment Short-Form scale. The functional limitations were assessed using the activities of daily living (ADL) scale, namely Barthel Index and Lawton Scale. The association between nutritional status and ADL was assessed using multivariate logistic regression models.

**Results:** In this study, the prevalence of malnutrition was 20.8 % among centenarians, basic ADL (BADL) limitation was 28.6 %, and instrumental ADL (IADL) limitation was 64.7 %. As the nutritional status deteriorated, the risk of ADL limitations increased in total population (BADL limitation: OR = 17.060, 95 % CI: 8.093-35.964; IADL limitation: OR = 11.221, 95 % CI: 5.853-21.511;  $p$  for trend < 0.001). Similar results were found in both men and women after stratifying sex but were more prominent in women.

**Conclusions:** Malnutrition is associated with functional limitations among centenarians in China and more pronounced among women.

**Keywords:** Centenarians, Malnutrition, Functional limitations, ADL, MNA-SF

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## Background

The global older population is increasing; this makes us facing the aging population and the health problems of the older. Because in the aging process, the human body inevitably experiences various functional declines; the problem of functional limitations [1] and deterioration of nutritional status [2] are more prominent.

Aging is a complex process representing a myriad of overlapping sets of influences and changes that accrue over time [3]. With the decline of muscle strength and physical function during aging, the older will face a high risk of physical function limitations [4]. Existing studies on function limitations caused by aging have also found that unhealthy lifestyles (e.g., lack of physical activity) and chronic diseases (e.g., diabetes, hypertension, and heart disease) are related to function limitations in later life activities [5, 6].

Malnutrition is associated with many adverse events in the aging process of the older [7], which heavily affect health status and life quality [8]. Especially in terms of function, it has been proved that malnutrition can lead to functional limitations in the older [9–11]. This is because nutritional status may trigger changes in the structure and function of muscles. There are functional limitations and physical disability in older caused by muscle loss and other reasons [12].

However, the research on the relationship between nutritional status and functional limitations of centenarians is limited. Current research mainly focuses on European populations and the sick older [13–16], with a lack of studies on Asian populations and community older. Centenarians, as the “template population” of population aging, have reference value for the extension of their life span and health to the general older population [17]. The longevity of centenarians in China’s Hainan Province is closer to natural longevity than that of those in areas with higher level of economic and medical. This provides a unique sample for the study of nutritional and functional limitations of the natural longevity population. Therefore, this study aims to identify the association between nutritional status and functional limitations among Chinese centenarians in community, and to supplement the evidence for this association in the Asian centenarian population.

## Methods

### Study design and participants

We performed a cross-sectional analysis with the data of centenarians-based from the China Hainan Centenarian Cohort Study (CHCCS) from 2014 to 2016. The study sample of CHCCS was drawn from Hainan province, China through a full sample survey process [18]. The following inclusion criteria were used to recruit participants: (1) was 100 years or older by 1 June 2014; (2)

volunteered to participate in the study and provided written informed consent; and (3) can get in touch with centenarians. Briefly, CHCCS is a study aiming to investigate health determinants and aspects of the centenarian population living in Hainan, China.

In 2014, at the time of the baseline survey, the older aged 100 years or over were considered eligible. Examining the ID numbers and on-site confirmations of all participants led to the choice of 1,473 centenarians as the target sample. Finally, centenarians who were unable to participate in all surveys were excluded, including 268 older who died before the interview, 124 older who unable to participate in the physical examination, and 79 older who declined to participate. 1,002 centenarians (180 men and 822 women) were included in our survey. These centenarians were not living in institutions, such as nursing homes. They live either with their families or alone in the community. As of the end of the survey, all the 1002 centenarians were alive.

### Data collection and definitions

In this survey, nurses familiar with the situation and language of the survey area completed questionnaires survey, physical examinations, and laboratory tests. In rare participants (e.g., centenarians with cognitive impairment), relatives of the centenarian were interviewed. Data were collected and sorted by two fully trained staff using the same equipment and software.

Basic characteristics included age, sex, educational level, residence type, physical activity, BMI, hematologic indicators, and chronic diseases. Age was ascertained from national ID cards. Educational level was categorized into “primary school and below” and “junior high school and above”. The residence type was categorized into “living alone” and “living with family”. The physical activity was assessed by answering “how many times did you do physical activities related to independent life per week”. We defined doing physical activities more than once a week as “physical activity”. Otherwise, it is “lack of physical activity”.

Body Mass Index (BMI) was calculated by weight and height. Weight and height were measured on a horizontal platform scale and a wall-mounted stadiometer to the nearest and 0.1 kg and 0.1 cm, respectively. Each parameter was measured twice, and the reported results were the averages of these duplicate measurements. Samples of venous blood were collected and transported by a standardized process, which analyzed by an automatic biochemical analyzer (COBAS c702; Roche Products Ltd., Basel, Switzerland) in the Hainan Branch of the Chinese People’s Liberation Army General Hospital. The hematologic indicators included hemoglobin (Hb), serum albumin (ALB), and total cholesterol (TC).

Participants were asked whether they had any current chronic diseases including diabetes, hypertension, and heart disease. Chronic diseases were identified based on self-reports combined with the medical records of the participants. For example, diabetes was defined as fasting blood glucose  $\geq 7.0$  mmol/L, or postprandial blood glucose  $\geq 11.1$  mmol/L, or currently using hypoglycemic drugs.

### Functional limitations

The functional limitations were assessed using the activities of daily living (ADL) scale [19], which was usually used to estimate the decline or even loss of body function among older. Activities of daily living are basic activities necessary for people to take care of themselves, maintain personal hygiene, and carry out independent social activities in daily life [20]. The Barthel index and Lawton scale evaluated basic ADLs (BADLs) and instrumental ADLs (IADLs), respectively; their validity has been well established in Chinese older [21, 22] and centenarians [23]. The more scores centenarians obtained in Barthel index and Lawton scale, the better their ADL. In this study, we used face-to-face questionnaires to assess centenarians' ADL and conduct on-site inspections to ensure effectiveness and reliability.

The Barthel index includes the fundamental skills typically needed to manage basic physical needs, comprised of various functional skills in different areas [24]. It includes ten items including bowel control, bladder control, grooming, bathing, toilet use, dressing, feeding, stair climbing, transferring from bed to chair, and mobility [19]. The final score ranges from 0 (full dependence) to 100 (full independence), in 5-point intervals. Lawton scale is an appropriate tool for assessing independent living skills, which includes using the telephone, food preparation, housekeeping, laundry, handling finances, shopping, mode of transportation, and using own medications [25]. The final score ranges from 0 (full dependence) to 8 (full independence), in 1-point intervals.

As a special group, the activities of centenarians may be different from other age clusters. Quantifying their ADL using the same score would be unfair. Therefore, binary variables of ADL/IADL were constructed, which were "BADL limitation" and "No BADL limitation" / "IADL limitation" and "No IADL limitation. We define "BADL limitation" as  $\leq 60$  points [26], and "IADL limitation" as  $\leq 2$  points [13].

### Nutritional status

Nutritional status was assessed by the Mini Nutritional Assessment Short-Form (MNA-SF). It has been verified and widely accepted malnutrition risk screening in the older, with good sensitivity and high correlation [27]. The total weighted MNA-SF scores range from 0 to 14,

with 12 to 14 indicating normal nutrition, 8 to 11 indicating being at the risk of malnutrition, and  $\leq 7$  indicating malnutrition. In this study, they were represented by "normal", "at-risk", and "malnutrition".

### Statistical analyses

Descriptive statistics were performed using mean  $\pm$  standard deviation for normally distributed continuous variables, and median (M)  $\pm$  interquartile range (IQR) for non-normally distributed continuous variables. Categorical variables were expressed as n (%). Statistical differences were compared using independent samples T-test for continuous variables and Chi-square test for categorical variables. Logistic regression models were employed to estimate the odds ratios (ORs) and 95 % confidence interval (CI) of risk factors associated with functional limitations. Meanwhile, this binary coding of ADL/IADL variables was also used as dependent variables in the multivariable regression analysis, and BMI was excluded from the model because of multicollinearity with MNA-SF score. Last, according to different population, we divided them into three groups: total group, man group and woman group. And considered three types of variables: basic characteristics (age, sex, educational level, residence type, physical activity), hematological indicators (Hb, ALB, TC), and chronic diseases (diabetes, hypertension, heart disease). Run a logistic regression model (crude model) that includes only covariates of nutritional status, following by entering basic characteristic variables (model 1), hematologic indicators variables (model 2), and chronic diseases variables (model 3). Statistical significance was set at 0.05 (two sides). IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, N.Y., USA) and statistical software packages R (<http://www.R-project.org>, The R Foundation) were utilized for statistical data analysis.

### Results

Table 1 summarizes the basic characteristics of centenarians in different nutritional status. The study participant was on average 102 years old with 82.0 % women. Most centenarians had primary education or below (98.0 %), live with their families (86.1 %), and lack of activity (87.1 %). As the nutritional status declined, hematologic indicators also declined. Participants had a higher prevalence of hypertension, and a lower prevalence of diabetes and heart disease. There was no statistical difference in the prevalence of diabetes, hypertension, and heart disease under different nutritional status.

Figure 1 shows the proportion of centenarians with BADL/IADL limitation under the different nutritional status. In the total sample, the prevalence of malnutrition was 20.8 % (208/1002), BADL limitation was 28.6 % (287/1002), and IADL limitation was 64.7 % (648/1002).

**Table 1** Distribution of baseline characteristics of centenarians in different nutritional status

Characteristics	Total (n = 1002)	Nutritional status			p-Value <sup>a</sup>
		Normal (n = 123)	At-risk (n = 671)	Malnutrition (n = 208)	
Age, M (IQR), years	102.0(3.0)	102.0(3.0)	102.0(3.0)	102.0(3.0)	0.533
Woman, %	822(82.0)	93(75.6)	545(81.2)	184(88.5)	0.008
Primary school and below, %	982(98.2)	7(5.7)	11(1.6)	2(1.0)	0.006
Living with families, %	863(86.1)	104(84.6)	565(84.2)	194(93.3)	0.004
Physical activity, %	129(12.9)	23(18.7)	93(13.9)	13(6.3)	0.002
BMI, M (IQR)	17.9(16.0-19.9)	21.8(20.3-23.8)	17.8(15.9-19.5)	17.1(16.0-18.4)	< 0.001
Hb, M (IQR), g/L	114.0(20.0)	119.0(18.0)	114.0(19.0)	112.0(21.8)	< 0.001
ALB, M (IQR), g/L	4.6(1.2)	4.8(1.2)	4.6(1.1)	4.5(1.3)	< 0.001
TC, M (IQR), mmol/L	38.5(5.1)	40.2(3.7)	38.6(4.9)	37.4(6.2)	< 0.001
Diabetes, %	96(9.6)	13(10.6)	63(9.4)	20(9.6)	0.920
Hypertension, %	757(75.5)	99(80.5)	501(74.7)	157(75.5)	0.385
Heart disease, %	41(4.1)	5(4.1)	26(3.9)	10(4.8)	0.839

<sup>a</sup> All p-values were significant at P < 0.05

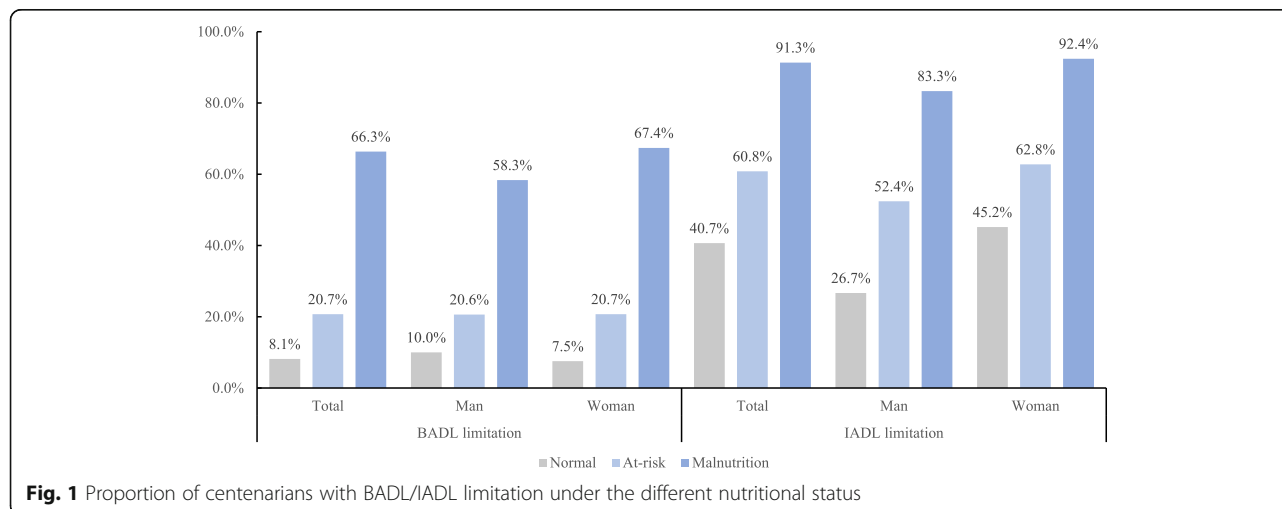
The malnutrition group had a significantly higher prevalence of ADL limitation than the prevalence of other groups. There was no statistical difference between men and women with BADL limitation ( $p = 0.120$ ), while IADL limitation did ( $p < 0.001$ ).

Figure 2 shows the proportion of centenarians who are functionally independent under different nutritional status, and the odds ratio of malnutrition group to normal nutrition group. The proportion of centenarians with various dependencies increased with nutritional status deteriorated. In BADL, bladder control is a relatively independent behavior (28/1002); the proportion of bladder control is also lower than other behavior under different nutritional status. Stair climbing was the least independent behavior. In IADL, laundry is the most independent behavior (532/1002), and mode of transportation is the least independent behavior.

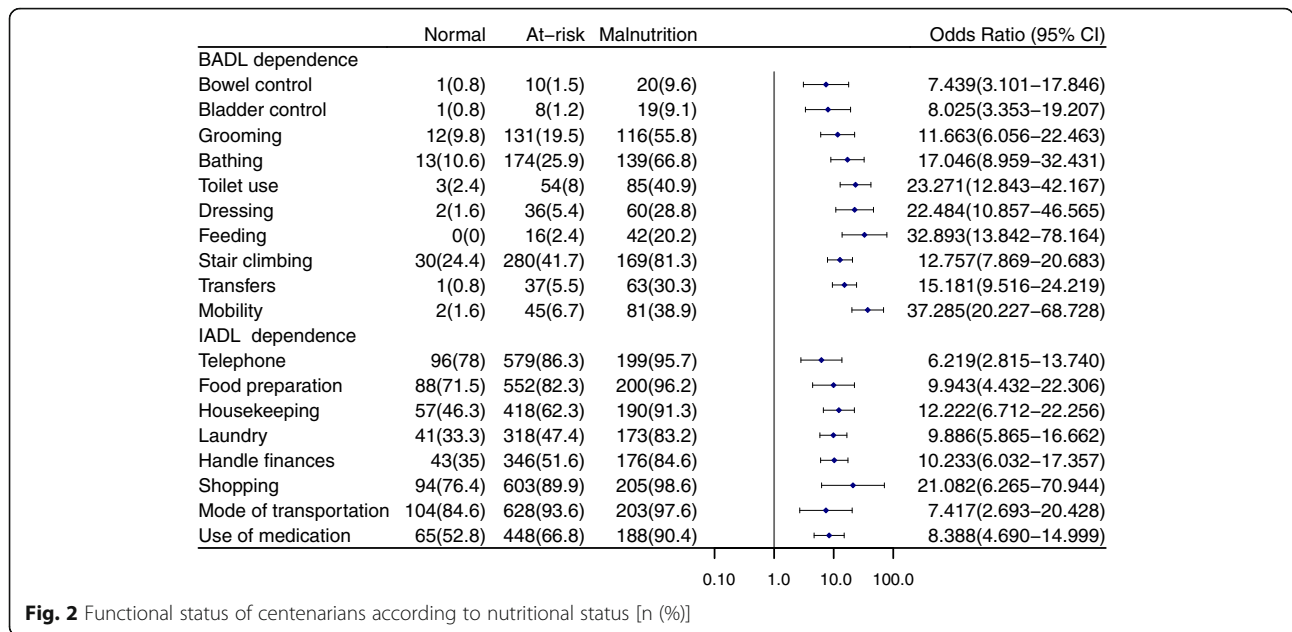
Tables 2 and 3 present the results of multivariable logistic regression analysis for the association between nutritional status and BADL/IADL. As the nutritional status deteriorated, the risk of ADL limitations gradually increased ( $p$  for trend < 0.001). In the total population, the OR of BADL limitation for malnutrition centenarians was 17.060 (95 % confidence interval [CI]: 8.093-35.964), and that of IADL was 11.221 (95 % CI: 5.853-21.511). After gradually adjusting the covariates, the OR was weakened but in the same direction. Similar results were found in both men and women but were more prominent in women after stratifying sex.

**Discussion**

This is a study about the association between nutritional status and functional limitations among centenarians



**Fig. 1** Proportion of centenarians with BADL/IADL limitation under the different nutritional status



**Fig. 2** Functional status of centenarians according to nutritional status [n (%)]

based on a large sample of the Chinese community population. Some studies have found that centenarians were facing functional limitations. A study describing centenarians in Mexico City showed that their ADL limitations proportion was 70.7 % [28]. Similarly, a study of 43 centenarians in Costa Rica showed that there were only 2 centenarians with independent BADL function and only 1 with IADL independence [15]. In developed countries, similar results were also found [29–31].

Consistent with studies on centenarians in other parts of China, the prevalence of BADL limitation and malnutrition among centenarians in Hainan is low, but IADL is high [32–34]. The reason for this difference is Lawton IADL assessed the instrumental activities of daily living, which require greater complexity of the neurophysical functions [35].

Although the results reported by each country and region were relatively consistent, there were no specific

**Table 2** Multivariable logistic regression analysis for the association between nutritional status and BADL limitation <sup>a, b</sup>

	Nutritional status			p for trend
	Normal	At risk	Malnutrition	
Total population				
Crude model	1	2.952(1.506–5.787)	22.277(10.978–45.208)	<0.001
Model 1	1	2.864(1.448–5.664)	20.955(10.169–43.179)	<0.001
Model 2	1	2.388(1.190–4.792)	16.770(7.972–35.280)	<0.001
Model 3	1	2.390(1.189–4.804)	17.060(8.093–35.964)	<0.001
Man				
Crude model	1	2.340(0.658–8.319)	12.600(2.977–53.323)	<0.001
Model 1	1	2.457(0.652–9.260)	12.438(2.702–57.259)	<0.001
Model 2	1	2.201(0.538–9.004)	19.033(3.454–104.881)	<0.001
Model 3	1	2.262(0.548–9.334)	19.658(3.497–110.510)	<0.001
Woman				
Crude model	1	3.214(1.447–7.136)	25.390(11.074–58.213)	<0.001
Model 1	1	3.176(1.421–7.102)	25.071(10.790–58.253)	<0.001
Model 2	1	2.731(1.196–6.240)	19.913(8.340–47.548)	<0.001
Model 3	1	2.765(1.207–6.336)	20.824(8.680–49.960)	<0.001

<sup>a</sup> Crude model: None adjusted; Model 1: Adjusted for age, sex, educational level, residence types, physical activity; Model 2: Model 1 plus hemoglobin, serum albumin, total cholesterol; Model 3: Model 2 plus diabetes, hypertension, heart disease

<sup>b</sup> Described as OR (95 %CI)

**Table 3** Multivariable logistic regression analysis for the association between nutritional status and IADL limitation <sup>a</sup>

	Nutritional status			p for trend
	Normal	At risk	Malnutrition	
Total population				
Crude model	1	2.265(1.531–3.351)	15.411(8.436–28.153)	<0.001
Model 1	1	2.221(1.457–3.385)	13.298(7.069–25.019)	<0.001
Model 2	1	1.919(1.247–2.952)	10.880(5.700–20.769)	<0.001
Model 3	1	1.908(1.236–2.945)	11.221(5.853–21.511)	<0.001
Man				
Crude model	1	3.025(1.253–7.304)	13.750(3.585–52.740)	<0.001
Model 1	1	2.929(1.126–7.617)	11.802(2.828–49.255)	<0.001
Model 2	1	2.483(0.947–6.514)	9.941(2.301–42.960)	<0.001
Model 3	1	2.629(0.958–7.214)	11.146(2.452–50.664)	<0.001
Woman				
Crude model	1	2.046(1.313–3.188)	14.745(7.462–29.134)	<0.001
Model 1	1	2.099(1.308–3.368)	13.986(6.856–28.534)	<0.001
Model 2	1	1.828(1.124–2.972)	11.308(5.457–23.432)	<0.001
Model 3	1	1.858(1.138–3.035)	12.007(5.761–25.027)	<0.001

<sup>a</sup> The adjusted covariates in models are the same as in Table 2

analysis of the impact of the nutritional status of centenarians on the activities. This study focuses on centenarians in the community, and the association between nutritional status and functional limitations. In this study of these extreme survivors, we found that malnutrition was significantly associated with the limitations of BADL and IADL among centenarians.

The results were consistent with previous studies showing that there are more woman centenarians than man centenarians in the same area [4, 14, 36]. But the functional limitations faced by man and woman were similar. The association between nutritional status and functional limitations is complex because it involves multiple system linkages. As the nutritional status deteriorated, the risk of ADL limitations gradually increased. There were different statistical differences between men and women in BADL/IADL, and one of the reasonable explanations is the difference in the education level. In this study, women’s education level was significantly lower than men’s education level (junior high school and above, 0.5%: 8.9%). It also requires further research to confirm the mechanism. Women are more affected by the impact of nutrition on activity, which suggests that we need to pay more attention to woman centenarians.

The results also extend the findings of the previous studies: the differences in the association between malnutrition and impaired ADL items for centenarians in different countries. In the study of centenarians in

Sweden [4], Denmark [14], and Japan [37], bathing suffered the most damage in BADL, while in China it was “mobility” [36]. Although the highest proportion of impaired items is stair climbing in this study, the proportion of transfers is similar to centenarians in other parts of China. There may be two reasons for this difference. First, most centenarians in Hainan live in bungalows, and they rarely use stairs. Second, bed/chair transfer can be used to screen for long-term risks of functional limitations [38], which is more obvious for extreme survivor.

This study has some limitations. First, this research was a cross-sectional study that limits the ability to determine the causal relationship and reason between nutritional status and functional limitations. Second, we cannot obtain the association between nutritional status and functional limitations for centenarians who unable to participate in the physical examination. Last, compared with the current well-known cohort studies, the sample size of centenarians in CHCCS is smaller. It had an impact on the accuracy of the research.

**Conclusions**

This study provides evidence that malnutrition is associated with functional limitations among centenarians in China and more pronounced among women. Although the prevalence of ADL limitations among centenarians in Hainan, China is low, the impaired activities of the older caused by malnutrition still needs attention. Strengthening the nutrition of the older is of practical significance for promoting healthy aging.

### Abbreviations

ADL: activities of daily living; BADL: basic ADL; IADL: instrumental ADLs; MNA-SF: the Mini Nutritional Assessment Short-Form; CHCCS: the China Hainan Centenarian Cohort Study; BMI: Body Mass Index; Hb: hemoglobin; ALB: serum albumin; TC: total cholesterol; M: median; IQR: interquartile range; OR: odds ratios; CI: confidence interval

### Acknowledgements

The authors would like to thank all centenarians who participated in the study, as well as the community doctors and nurses who served this study.

### Authors' contributions

ML conceptualized the study, WPJ, KH and SSW took responsibility for data handling and statistical analysis. YS drafted the manuscript. YH and ML contributed to interpretation of data, critical revision of the manuscript, and study supervision. All authors read and approved the final manuscript.

### Funding

Not applicable.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Declarations

#### Ethics approval and consent to participate

All the experiment protocol for involving humans was in accordance to guidelines of national, international, institutional, and Declaration of Helsinki in the manuscript. Both studies were approved by the Ethics Committee of the Hainan Branch of the Chinese People's Liberation Army General Hospital before the project started (301hn1201601) and all participants provided written informed consent. Data were anonymized and de-identifiable with no personal information, with careful protection on confidentiality.

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare that they have no competing interests.

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Received: 2 February 2021 Accepted: 2 June 2021

Published online: 21 June 2021

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