Role of Muscle Mass and Nutritional Assessment Tools in Evaluating the Nutritional Status of Patients With Locally Advanced Nasopharyngeal Carcinoma

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Objective: This study was to explore the role and necessity of muscle mass [fat-free mass index (FFMI) and appendicular skeletal muscle index (ASMI) measured by bioelectrical impedance analysis (BIA)] in nutritional status evaluation of patients with locally advanced (II, IVa) nasopharyngeal carcinoma (NPC).

Methods: One hundred and thirty locally advanced NPC patients were recruited. Their nutritional status was assessed by albumin (ALB), body mass index (BMI), Nutritional Risk Screening 2002 (NRS 2002), Patient generated-Subjective Global Assessment (PG-SGA), and muscle mass. Consistency test and McNemar test were used to evaluate the consistency of muscle mass with ALB, BMI, NRS 2002, and PG-SGA, and correlation analysis was performed on muscle mass and PG-SGA or BMI.

Results: 61/130 (46.9%) of the patients had nutritional risks according to NRS 2002, 68/130 (53.1%) of the patients had malnutrition according to PG-SGA assessment. FFMI and ASMI could determine the loss of muscle mass that cannot be detected by albumin (30.2 and 65.6%), BMI (28.0 and 35.3%), NRS 2002 (26.1 and 25.0%), and PG-SGA (18.6 and 55.6%). McNemar test showed that the malnutrition results assessed by FFMI and BMI were inconsistent ($P < 0.001$), but further Pearson correlation analysis showed that BMI was positively correlated with FFMI ($r_s = 0.300, P = 0.001$).

Conclusion: The commonly used nutritional assessment scale/parameters cannot identify the muscle mass loss in patients with locally advanced NPC. Analysis of human body composition is important for nutritional assessment in patients with locally advanced NPC.

Keywords: body mass index, fat-free mass index, nasopharyngeal carcinoma, body composition analysis, nutritional status assessment
INTRODUCTION

Nasopharyngeal carcinoma (NPC) is a type of malignant tumor originated from nasopharynx and is one of the most common head and neck malignant tumors in China (1). Due to the concealed anatomy of the nasopharynx, the early symptoms of the patients are not obvious, and our hospital found that 70% of the 1,200 patients present with locally advanced stages (stage III and IVa) at the time of diagnosis. Besides the tumor burden, NPC patients would be affected simultaneously by side effects of chemoradiotherapy and sequence radiotherapy, and would often be accompanied by varying degrees of nutritional risk or malnutrition, such as wasting, anemia, and hypoproteinemia, which may directly affect the control and prognosis of the tumor (2–4). Therefore, early detection of the NPC patients at nutritional risk, timely nutritional treatment may reduce the incidence of malnutrition and may improve the effectiveness of cancer treatment.

Expert Consensus on nutrition therapy for head and neck cancer in Mainland and Taiwan China, and the United Kingdom recommended either Nutritional Risk Screening 2002 (NRS 2002) as a nutritional risk screening tool or Patients Generated-Subjective Global Assessment (PG-SGA) as a nutritional assessment tool (5, 6). Body mass index (BMI) and albumin (ALB) are also nutritional assessment scales or parameters currently used in patients with NPC.

But the commonly used nutritional assessment scale/parameters cannot recognize the muscle loss, and the harm of muscle mass attenuation in patients with locally advanced NPC has not been valued in China. The European Society of Clinical Nutrition and Metabolism (ESPEN) suggested reduced fat-free mass index (FFMI) combined with %weight loss [alternatively, BMI < 20 kg/m² (<70 years)/<22 kg/m² (70 or older)] as one of the two alternative criteria to diagnose malnutrition (7). Asian working groups for sarcopenia 2019 recommended appendicular skeletal muscle mass index (ASMI) as an indicator for muscle mass (8). Patients with malignant tumors, such as liver cancer, gastric cancer, colorectal cancer, and head and neck cancer, usually have muscle mass decreases, which will affect the outcome of the diseases (8–11). Presence of low ASMI + low muscle strength or low physical performance was identified as independent predictor of reduced overall survival among cirrhotic patients with hepatocellular carcinoma (12).

This study was to investigate the consistency of FFMI and ASMI (measured by Bioelectrical impedance Analysis, BIA) with the commonly used nutritional assessment scale/parameters (NRS 2002, PG-SGA, BMI, and ALB), and to explore the effect of body composition analysis on nutritional assessment in patients with locally advanced NPC.

MATERIALS AND METHODS

Subjects

This study recruited 130 patients with locally advanced NPC diagnosed from June 2018 to October 2019. Informed consent was signed by all of the recruited patients. The inclusion criteria were: (1) age 18–90 years old, (2) with newly diagnosed NPCs according to the diagnostic criteria, (3) the patients had no more than 10 times of radiotherapy and no more than three times of chemotherapy, (4) no serious ascites and edema, and (5) no surgery before 8 a.m. the next day and the hospital stay was more than 24 h.

Methods

The InBodyS10 analyzer, a multifrequency BIA (Biospace Co., Ltd., Seoul, Korea) was used to estimate the human body composition. InBody uses an eight-point quadrupole electrode system method to evaluate the impedance of small alternating current applied to the body at three specific frequencies (5, 50, and 250 kHz) and six specific frequencies (1, 5, 50, 250, 500, and 1,000 kHz). The BIA measurements were conducted by trained personnel in accordance with the standardized procedures.

The enrolled patients were firstly diagnosed with nasopharyngeal carcinoma and had no more than 10 times of radiotherapy and no more than three times of chemotherapy. BIA was measured when patients were firstly enrolled. Patients had an overnight fast, emptied the bladder by urinating, took off the clothes, and kept a standing posture during the measurement, during which the ambient temperature remained at 25°C.

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\text{FFMI} = \frac{\text{fat free mass}}{\text{height} \times \text{height}}. \quad \text{ASMI} = \frac{\text{appendicular skeletal muscle mass}}{\text{height} \times \text{height}}. \quad \text{ALB} = \frac{\text{an albumin}}{\text{aliquot mass}}
\]

FFMI = fat free mass/(height × height). FFMI of <17 kg/m² for men or <15 kg/m² for women was defined as low FFMI (+) according to the cut-off values for FFMI by ESPEN (7). ASMI = appendicular skeletal muscle mass/(height × height). ASMI of <7 kg/m² for men or <5.7 kg/m² for women was defined as low ASMI (+) according to the cut-off values for ASMI by Asian-based reference (8).

Height and weight were measured at fasting status and shoe-free, respectively, and the BMI was calculated. BMI < 18.5 kg/m² indicates malnutrition (BMI +). Albumin was measured by fasting blood, Albumin <30 g/L was considered low Albumin (Albumin +). Nutritional risk was screened by NRS 2002, and a NRS 2002 score ≥3 was a suggestive of nutritional risk (NRS 2002 +) (13). PG-SGA was used for nutritional assessment, and PG-SGA score ≥4 indicated malnutrition (PG-SGA +) (14).

Statistical Analysis

SPSS version 17.0 (Statistical Product and Service Solutions, CA, USA) was used for statistical analysis. NRS 2002, PG-SGA, BMI, albumin, ASMI and FFMI were subjected to normal distribution test. Normally distributed variables (BMI, albumin, ASMI and FFMI) were expressed as mean ± standard deviation (SD); NRS 2002 was classified as 3, 4, and 5 scores. PG-SGA was classified as 0–3 scores, 4–8 scores, and ≥9 scores. Use McNemar test and consistency test analysis to perform consistency on NRS 2002, PG-SGA, BMI, or albumin with FFMI or ASMI. Pearson correlation analysis was used between FFMI or ASMI and BMI. A value of P < 0.05 was considered statistically significant.

RESULTS

General Characteristics

One hundred and thirty locally advanced NPC patients were recruited into the study, 67.7% of whom were men, the mean age is 49 ± 11.3 years old. The tumor, node and metastasis (TNM)
was 40.0

patients had an albumin lower than 30 g/L, and the mean albumin assessed with NRS 2002 (NRS 2002

patients had suspected malnutrition (PG-SGA cases (11.5%), and a score of equal or more than 5 were three

stages were ranging from III to IVa periods. The characteristics of patients and tumor are shown in Table 1.

The mean FFMI was 17.2 ± 1.7 kg/m². Of them, 30.8% had low FFMI, including 27 males and 13 females. The mean ASMI was 7.24 ± 0.54 kg/m². Of them, 35.4% had low ASMI, including 3 males and 2 females, and 30.8% had low BMI, including 27 males and 13 females. Only 3.8% of the patients had a BMI lower than 18.5 kg/m² (including three males and two females), and the mean BMI was 22.5 ± 2.28 kg/m². Only 0.8% of the patients had an albumin lower than 10 g/L, and the mean albumin was 40.0 ± 3.3 g/L (Table 2).

Almost half (46.9%) of the patients had nutritional risk when assessed with NRS 2002 (NRS 2002 ≥3 scores). The patients with a score of 3 were 43 cases (33.1%), a score of 4 were 15 cases (11.5%), and a score of equal or more than 5 were three cases (2.3%). An assessment with PG-SGA showed 53.1% of the patients had suspected malnutrition (PG-SGA ≥4 scores). The patients with a score of 0–3 were 61 cases (46.9%), a score of 4–8 were 37 cases (28.5%), and a score of equal or more than 9 were 32 cases (24.6%) (Table 2).

Baseline Characteristics by Age Stratification

The mean age of our patients was 49 ± 11.3 years old. We analyzed the FFMI, BMI and albumin of the patients by age stratification and found that FFMI was lower in patients with lower BMI. We found FFMI a growing polarization of trends with age. FFMI is lower in patients with age <40 years or older than 60 years (Table 3). We also analyzed the ASMI, BMI and albumin of the patients by age stratification and found that ASMI was lower in older patients. We found ASMI has no correlation with BMI (Table 3).

In addition, we added % of weight loss in Table 3 and found that FFMI was lowest on average among those who had lost more than 10% of their body weight in the last 6 months (FFMI 14.8 ± 2.21 kg/m²) (Table 3).

Consistency Between the Results of Human Body Composition and the Results of Nutritional Assessment Scales/Parameters

There was consistency between FFMI and BMI in the assessment of malnutrition (P = 0.001) but the consistency was poor (Kappa = 0.165). The rate of low FFMI was 30.8%, significantly higher than that of low BMI (3.8%), and the difference was statistically significant (P < 0.001). Inconsistency was noted between FFMI and albumin, FFMI and NRS 2002, FFMI and PG-SGA in the assessment of malnutrition (P = 0.132, 0.219, and 0.501, separately). The rate of low FFMI was 30.8%, significantly higher than that of low albumin (0.8%), and the difference was statistically significant (P < 0.001) (Table 4).

Among the patients whose nutritional risk screening by NRS 2002 was lower than the score of 3, the rate of low FFMI was 26.1%. Among the patients without malnutrition assessed by PG-SGA, the rate of low FFMI was 18.6%. And 28% of patients whose BMI was equal or more than 18.5 kg/m² have low FFMI. Among patients with albumin equal or

### Table 1 | Baseline characteristics of study sample (n = 130).

| Characteristics | Number of patients (%) | Characteristics | Number of patients (%) |
|-----------------|------------------------|----------------|------------------------|
| Sex             |                        |                |                        |
| Male            | 88 (67.7%)             | Female         | 42 (33.3%)             |
| Age (years)     | 49 ± 11.3              |                | 49 ± 11.3              |
| TNM stage       |                        |                |                        |
| Stage of treatment |                  |                |                        |
| I               | 0 (0.0%)               | II             | 0 (0.0%)               |
| II              | 80 (61.5%)             | III            | 80 (61.5%)             |
| III             | 45 (33.8%)             | IVa            | 45 (33.8%)             |
| Anorexia        | 0 (0.0%)               |                | 0 (0.0%)               |
| Food intake     |                        |                |                        |
| Sufficient      | 21 (16.2%)             | Insufficient   | 109 (83.8%)            |
| Seriously inadequate | 21 (19.3%)          | Slightly inadequate | 49 (44.9%)              |
| Moderately inadequate | 39 (35.8%)          |                | 39 (35.8%)             |
| Table 1: Baseline characteristics of study sample (n = 130).

TNM, tumor, node, and metastasis; AJCC, American Joint Committee on Cancer; Seriously inadequate: Intake less than half of targets; Moderately inadequate: Intake was between half and three quarters of targets; Slightly inadequate: Intake more than three quarters of targets.

### Table 2 | Nutritional status and human body composition of locally advanced NPC patients (n = 130).

| Parameters       | ± s or M ± QR |
|------------------|---------------|
| Height (cm)      | 163.5 ± 9.00  |
| Weight (kg)      | 60.00 ± 9.47  |
| FFMI (kg/m²)     | 17.21 ± 1.65  |
| ASMI (kg/m²)     | 7.24 ± 0.54   |
| BMI (kg/m²)      | 22.54 ± 2.28  |
| Albumin          | 40.05 ± 3.28  |
| NRS 2002 score   |               |
| 3                | 43 (33.1%)    |
| 4                | 15 (11.5%)    |
| 5                | 3 (2.3%)      |
| PG-SGA score     |               |
| 0–3              | 61 (46.9%)    |
| 4–8              | 37 (28.5%)    |
| ≥9               | 32 (24.6%)    |

± s refers to mean ± standard deviation (SD), or M ± QR refers to median ± quartile range.

FFMI, fat-free mass index; ASMI, appendicular skeletal muscle mass; BMI, body mass index; NRS2002, nutrition risk screening 2002; PG-SGA, Patient Generated Subjective Global Assessment.
TABLE 3 | Baseline characteristics of study sample stratified by age and % weight loss (n = 130).

| Age stratification (years old) | Number (%) | FFMI (kg/m²) | ASMI (kg/m²) | BMI (kg/m²) | Albumin (g/L) |
|-------------------------------|------------|--------------|--------------|-------------|---------------|
| ≤30                           | 6 (4.6%)   | 14.6 ± 0.55  | 7.69 ± 0.34  | 18.9 ± 2.55 | 41.1 ± 3.32   |
| 31–40                         | 11 (8.5%)  | 15.9 ± 1.72  | 7.35 ± 0.25  | 20.4 ± 1.49 | 41.4 ± 3.76   |
| 41–50                         | 55 (42.3%) | 17.8 ± 0.98  | 7.31 ± 0.86  | 23.3 ± 1.64 | 40.6 ± 2.55   |
| 51–60                         | 42 (32.3%) | 17.6 ± 1.21  | 7.32 ± 0.44  | 23.2 ± 2.12 | 40.1 ± 3.10   |
| 61–70                         | 16 (12.3%) | 15.8 ± 1.55  | 6.57 ± 0.62  | 20.7 ± 0.67 | 37.8 ± 1.74   |

% of weight loss

<5%                                | 94 (72.3%) | 16.1 ± 0.84  | 7.20 ± 1.59  | 22.7 ± 2.56 | 40.4 ± 2.75   |
Between 5 and 10%                | 26 (20.0%) | 17.6 ± 1.98  | 7.17 ± 1.24  | 21.7 ± 1.45 | 40.3 ± 3.67   |
More than 10%                   | 10 (7.7%)  | 14.8 ± 2.21  | 7.83 ± 0.85  | 23.1 ± 2.04 | 37.9 ± 0.96   |

FFMI, fat-free mass index; ASMI, appendicular skeletal muscle mass; BMI, body mass index.

TABLE 4 | Consistency of the fat-free mass index (FFMI) and appendicular skeletal muscle mass (ASMI) with the nutritional scales/parameters in the nutritional assessment (n = 130).

| BIA | BMI | Albumin | NRS2002 | PG-SGA | Total |
|-----|-----|---------|---------|--------|-------|
|     | +   | -       | +       | -      | +     | -     |
| FFMI| 5 (100.0) | 35 (28.0) | 1 (100.0) | 39 (30.2) | 22 (36.1) | 18 (26.1) | 23 (32.4) | 17 (18.6) | 40 (30.8) |
|    | 0 (0.0) | 90 (72.9) | 0 (0.0)  | 90 (69.8) | 39 (63.9) | 51 (73.9) | 46 (67.6) | 44 (81.4) | 90 (69.2) |
| ASMI| 0 (0.0) | 46 (36.8) | 0 (0.0)  | 46 (35.7) | 28 (45.9) | 18 (26.1) | 23 (32.4) | 23 (37.7) | 46 (35.4) |
|    | 5 (100.0) | 79 (63.2) | 1 (100.0) | 83 (64.3) | 33 (54.1) | 51 (73.9) | 46 (67.6) | 38 (62.3) | 84 (64.6) |

FFMI, fat-free mass index; ASMI, appendicular skeletal muscle mass; BMI, body mass index; NRS2002, nutrition risk screening 2002; PG-SGA, Patient Generated Subjective Global Assessment.

FIGURE 1 | Consistency of the fat-free mass index with the nutritional scales/parameters in the nutritional assessment of locally advanced NPC patients (n = 130).

more than 30 g/L, the rate of low FFMI was as high as 30.2% (Figure 1).

There was consistency between ASMI and BMI in the assessment of malnutrition (P = 0.012) but the consistency was poor (Kappa = 0.092). The rate of low FFMI was 35.4%, significantly higher than that of low BMI (3.8%), and the difference was statistically significant (P < 0.001). Inconsistency was noted between ASMI and PG-SGA in the assessment of malnutrition (P = 0.961) (Table 4). Among the patients whose nutritional risk screening by NRS 2002 was lower than the score of 3, the rate of low ASMI was 25.0%. Among the patients without malnutrition assessed by
PG-SGA, the rate of low ASMI was 55.6%. And 35.3% of patients whose BMI was equal or more than 18.5 kg/m² have low ASMI. Among patients with albumin equal or more than 30 g/L, the rate of low ASMI was as high as 65.6% (Figure 2).

**DISCUSSION**

Patients with NPC often face multiple nutritional problems before, during, and after treatment because of the closeness of the cancer to organs that are critical for normal eating function. Dysgeusia, nausea, dysphagia, mucositis, xerostomia, and vomiting are the common treatment-related side effects that further impair the patient’s ability to maintain adequate oral intake. Regular assessment of the nutritional status of patients with nutritional risk and early initiation of nutritional therapy can improve the outcomes (15, 16).

ESPEN suggested reduced muscle mass as a selective criterion to diagnose malnutrition (7). The content of muscle mass reduction appeared in Global Leadership Initiative on Malnutrition (GLIM) assessment standard consensus.
Microalbuminuria is supported in ALD patients. The authors concluded that microalbuminuria is an independent predictor of higher BMI and lower muscle mass. In summary, the study indicates that microalbuminuria is associated with a higher BMI and lower muscle mass in patients with ALD. The results suggest that individuals with microalbuminuria should receive careful monitoring for BMI and muscle mass to prevent further complications. Further studies are needed to validate these findings and investigate the underlying mechanisms.
provided their written informed consent to participate in this study.

**AUTHOR CONTRIBUTIONS**

ML led the study design and approved the final version of the manuscript. XP, HL, and ML collected and analyzed the data. XP, HL, and ML drafted the manuscript. All authors have read and approved the manuscript.

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**REFERENCES**

1. Miao J, Xiao W, Wang L, Han F, Wu H, Deng X, et al. The value of the Prognostic Nutritional Index (PNI) in predicting outcomes and guiding the treatment strategy of nasopharyngeal carcinoma (NPC) patients receiving intensity-modulated radiotherapy (IMRT) with or without chemotherapy. J Cancer Res Clin Oncol. (2017) 143:1263–73. doi: 10.1007/s00432-017-2360-3
2. Blanchard P, Lee A, Marguet S, Leclercq J, Ng W, Ma J, et al. Chemotherapy and radiotherapy in nasopharyngeal carcinoma: an update of the MAC-NPC meta-analysis. Lancet Oncol. (2015) 16:645–55. doi: 10.1016/S1470-2045(15)70126-9
3. Xiao W, Chan C, Fan Y, Leung D, Xia W, He Y, et al. Symptom clusters in patients with nasopharyngeal carcinoma during radiotherapy. Eur J Oncol Nurs. (2017) 28:7–13. doi: 10.1016/j.ejon.2017.02.004
4. Guan Y, Liu S, Wang H, Guo Y, Xiao W, Chen C, et al. Long-term outcomes of a phase II randomized controlled trial comparing intensity-modulated radiotherapy with or without weekly cisplatin for the treatment of locally recurrent nasopharyngeal carcinoma. Chin J Cancer. (2016) 35:20. doi: 10.1186/s40880-016-0081-7
5. Lin M, Shuang P, Chang W, Chang P, Feng H, Yang M, et al. Consensus and clinical recommendations for nutritional intervention for head and neck cancer patients undergoing chemoradiotherapy in Taiwan. Oral Oncol. (2018) 81:16–21. doi: 10.1016/j.oraloncology.2018.03.016
6. Talwar B, Donnelly R, Skelly R, Donaldson M. Nutritional management in head and neck cancer: United Kingdom National Multidisciplinary Guidelines. J Laryngol Otol. (2016) 130:S32–40. doi: 10.1017/S0022215116000402
7. Cederholm T, Bosaeus I, Barazzoni R, Bauer J, Van Gossum A, Klek S, et al. Diagnostic criteria for malnutrition–an ESPEN consensus statement. Clin Nutr. (2015) 34:335–40. doi: 10.1016/j.cnu.2015.03.001
8. Chen L, Woo J, Assantachai P, Auyueng T, Chou M, Lijima K, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. (2020) 21:300–7. doi: 10.1016/j.jamda.2019.12.012
9. Changi N, Bril S, Emmetot-Vonk M, de Bree R. Sarcopenia is a prognostic factor for overall survival in elderly patients with head-and-neck cancer. Eur Arch Otorhinolaryngol. (2019) 276:1475–86. doi: 10.1007/s00405-019-05361-4
10. Lin S, Lin Y, Kang B, Yin C, Chang K, Chi C, et al. Sarcopenia results in poor survival rates in oral cavity cancer patients. Clin Otolaryngol. (2020) 45:327–33. doi: 10.1111/coa.13481
11. Park Y, Kim J, Kim B, Lee K, Lee J, Kim J, et al. Sarcopenia is associated with an increased risk of advanced colorectal neoplasia. Int J Colorectal Dis. (2017) 32:557–65. doi: 10.1007/s00384-016-2738-8
12. Begini P, Gigante E, Antonelli G, Carbonetti F, Iannicelli E, Anania G, et al. Sarcopenia predicts reduced survival in patients with hepatocellular carcinoma at first diagnosis. Ann Hepatol. (2017) 16:107–14. doi: 10.5064/16652681.1226821
13. Arends J, Bachmann P, Baracos V, Barthelemy N, Bertz H, Rozzetti F, et al. ESPEN guidelines on nutrition in cancer patients. Clin Nutr. (2017) 36:11–48. doi: 10.1016/j.clnut.2016.07.015
14. Mueller C, Compber C, Ellen D. ASPEN clinical guidelines: nutrition screening, assessment, and intervention in adults. J Parenter Enteral Nutr. (2011) 35:16–24. doi: 10.1177/0148607110389335
15. Bauer J, Capra S, Ferguson M. Use of the scored Patient-Generated Subjective Global Assessment (PG-SGA) as a nutrition assessment tool in patients with cancer. Eur J Clin Nutr. (2002) 56:779–85. doi: 10.1038/sj.ejcn.1601412
16. Kabarriti R, Bontempo A, Romano M, McGovern K, Asaro A, Viswanathan S, et al. The impact of dietary regimen compliance on outcomes for HNSCC patients treated with radiation therapy. Support Care Cancer. (2018) 26:3307–13. doi: 10.1007/s00520-018-4198-x
17. Ackerman D, Laszlo M, Provvisor A, Yu A. Nutrition management for the head and neck cancer patient. Cancer Treat Res. (2018) 174:187–208. doi: 10.1007/978-3-662-54241-8_11
18. Cederholm T, Jensen G, Correia M, Gonzalez M, Fukushima R, Higashiguchi T, et al. GLIM criteria for the diagnosis of malnutrition–a consensus report from the global clinical nutrition community. J Clin Nutr Sarcopenia Muscle. (2019) 10:207–17. doi: 10.1002/csm.12383
19. Cederholm T, Jensen G, Correia M, Gonzalez M, Fukushima R, Higashiguchi T, et al. GLIM criteria for the diagnosis of malnutrition–a consensus report from the global clinical nutrition community. Clin Nutr. (2019) 38:1–9. doi: 10.1016/j.clnu.2019.02.033
20. Ding H, Dou S, Ling Y, Zhu G, Wang Q, Wu Y, et al. Longitudinal body composition changes and the importance of fat-free mass index in locally advanced nasopharyngeal carcinoma patients undergoing concurrent chemoradiotherapy. Integr Cancer Ther. (2018) 17:1125–31. doi: 10.1177/1534735X18807969
21. Huang X, Ma J, Li L, Zhu X. Severe muscle loss during radical chemoradiotherapy for non-metastatic nasopharyngeal carcinoma predicts poor survival. Cancer Med. (2019) 8:6604–13. doi: 10.1002/cam4.2538
22. Prado C, Baracos V, McCargar L, Reiman T, Mourtzakis M, Tonkin K, et al. Sarcopenia as a determinant of chemotherapy toxicity and time to tumor progression in metastatic breast cancer patients receiving capecitabine treatment. Clin Cancer Res. (2009) 15:2920–6. doi: 10.1158/1078-0432.CCR-08-2242
23. Røder H, Henriksen C, Bohn S, O de Fey Vilbo A, Henriksen H, Kverner A, et al. Agreement between PG-SGA category and fat-free mass in colorectal cancer patients. Clin Nutr ESPEN. (2018) 27:24–31. doi: 10.1016/j.clnesp.2018.07.005
24. Lieffers J, Bathe O, Fassbender K, Winget M, Baracos V. Sarcopenia is associated with postoperative infection and delayed recovery from colorectal cancer resection surgery. Br J Cancer. (2012) 107:931–6. doi: 10.1038/bjc.2012.350
25. Martin L, Birdsell L, Macdonald N, Reiman T, Clandinin M, McCargar L, et al. Cancer cachexia in the age of obesity: skeletal muscle depletion is a powerful prognostic factor, independent of body mass index. J Clin Oncol. (2013) 31:1539–47. doi: 10.1200/JCO.2012.45.2722
26. Fürstenberg A, Davenport A. Assessment of body composition in peritoneal dialysis patients using bioelectrical impedance and dual-energy X-ray absorptiometry. Am J Nephrol. (2011) 33:150–6. doi: 10.1159/000324111
27. Prado C, Lieffers J, McCargar L, Reiman T, Sawyer M, Martin L, et al. Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study. Lancet Oncol. (2008) 9:629–35. doi: 10.1016/S1470-2045(08)70153-0
28. de van der Schueren M, Smoker M, Leistra E, Kruizenga H. The association of weight loss with one-year mortality in hospital patients, stratified by BMI and FFMI subgroups. *Clin Nutr.* (2018) 37:1518–25. doi: 10.1016/j.clnu.2017.08.024

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