Journal of Frailty, Sarcopenia and Falls

Review Article

The Influence of Muscle Morphology on Oncological Outcomes: A Review

Sophie Bastijns[1,2], Blanca Alabadi[3,4], Thiago Gonzalez Barbosa-Silva[5,6], Charlotte Beaudart[7,8], Kristoffer Brockhattingen[9,10], Scott Lamers[2], Karolina Piotrowicz[11], Carly Welch[12], Anne-Marie De Cock[1,2], Stany Perkisas[1,2]

[1]*ZAS (Ziekenhuis aan de Stroom), University Center for Geriatrics, Antwerp, Belgium;*
[2]*University of Antwerp, Antwerp, Belgium;*
[3]*Service of Endocrinology and Nutrition, Hospital Clínico Universitario of Valencia, Spain;*
[4]*INCLIVA Biomedical Research Institute, Valencia, Spain;*
[5]*Department of General Surgery, Faculty of Medicine, Federal University of Pelotas, Brazil;*
[6]*COCONUT Study Group, Brazil;*
[7]*Research Unit in Clinical Pharmacology and Toxicology (URPC), Namur Research Institute for Life Sciences (NARILIS), Department of Biomedical Sciences- Faculty of Medicine, University of Namur, Namur, Belgium;*
[8]*Vrije Universiteit Brussel, Rehabilitation Research- Department of Physiotherapy- Human Physiology and Anatomy, Jette, Belgium;*
[9]*Department of Geriatrics, Svendborg Hospital, Odense University Hospital – Odense, Denmark;*
[10]*Geriatric Research Unit, Department of Clinical Research, University of Southern Denmark, Odense, Denmark;*
[11]*Department of Internal Medicine and Gerontology, Faculty of Medicine, Jagiellonian University Medical College, Kraków, Poland;*
[12]*Department of Twin Research & Genetic Epidemiology, School of Life Course and Population Sciences, Faculty of Life Sciences and Medicine, King's College London, UK*

Abstract

Cancer is a common disease with significant impact on patients and society. Cancer and oncological treatment can negatively affect muscle, and muscle health impacts oncologic outcomes. This review studied the effect of different muscle parameters on oncologic outcomes. A systematic search was performed until April 2023. Parameters included were muscle thickness, cross-sectional area, skeletal muscle index, skeletal muscle mass, pennation angle, fascicle length, muscle density, echo intensity and elastography. Imaging methods included were computerized tomography, magnetic resonance imaging, ultrasound and dual-energy X-ray absorptiometry. Outcome parameters assessed were survival, chemotoxicity, surgical outcome, treatment response, duration of hospitalization, and quality of life. This review included 117 articles. Individuals with reduced skeletal muscle index or muscle density had lower survival rates, higher chemotoxicity and surgical complications, more hospitalizations, less treatment response and lower quality of life. Reduced muscle quantity and quality can impact oncological outcomes, either through primary or secondary sarcopenia. These findings warrant the need for holistic assessment by using comprehensive geriatric assessment to establish a correct treatment dosage. These results also suggest a beneficial effect of exercise and nutritional support. Further research can be useful to better understand the underlying mechanisms and optimize specific treatments for muscle in oncological patients.

Keywords: Oncology, Sarcopenia, Muscle, Body composition, Outcome

The authors have no conflict of interest.
Corresponding author: *Dr. Sophie Bastijns, Ziekenhuis aan de Stroom, Lindendreef 1, 2000 Antwerpen, Belgium*
E-mail: *Sophie.bastijns@zas.be*
Edited by: *Yannis Dionyssiotis*
Accepted *24 July 2025*

Introduction

Cancer is a prevalent disease with significant impact on a persons' quality of life, perceived health, and life expectancy[1-3]. It is one of the main causes of death worldwide, with more than 10 million deaths in 2020[1]. The most prevalent cancer types are breast, lung, colorectal, prostate, skin and stomach. One of the consequences of cancer and cancer treatment is muscle wasting, a condition with reduced muscle mass that negatively impacts prognosis and quality of life[4].

Muscle health is gaining increasing interest not only in an oncological setting but also in other medical fields. While awaiting the currently ongoing global definition of sarcopenia, which is a work in progress by the Global Leadership Initiative on Sarcopenia (GLIS)[5], the most updated definition states that sarcopenia is a muscular disease with low strength as key feature, combined with low muscle quantity or quality[6]. This occurs mainly in older persons but can also appear earlier in life or even in children[6]. Sarcopenia can be primary and thus age-related, however certain disease states, such as cancer but also declines in nutritional intake and physical activity, can induce secondary sarcopenia[6,7]. Sarcopenia is closely linked with cachexia, which is defined as a multifactorial syndrome with severe loss of weight due to an underlying disease and is cytokine-mediated. Cachexia mainly involves loss of fat and muscle[7,8]. Both sarcopenia and cachexia are common in cancer patients: 15-50% has sarcopenia, and 25-80% suffers from cachexia[7]. These two entities often co-exist and can exacerbate each other[7].

Different imaging methods are available to evaluate muscle status. Dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) measure muscle quantity. For these techniques cut-off values have been established. For computed tomography (CT) measurements cut-off values for sarcopenia have been more recently proposed[9]. However, multiple studies use different values. Magnetic resonance imaging (MRI) is often used in research and in oncological or surgical settings. Ultrasound (US) is a technique that is gaining more attention for the evaluation of muscle status since it is easily accessible, inexpensive, and non-invasive. The advantages of CT, MRI and US are that they can assess both muscle quantity and quality[6,10,11].

Muscle quantity can be assessed through muscle thickness (MT), cross-sectional area (CSA), skeletal muscle mass (SMM) and skeletal muscle index (SMI): skeletal muscle area divided by height. Muscle quality is possibly equally important, and covers assessments of histology, radiology, functionality or metabolism[5]. It is determined by a combination of metabolic features, number of type II fibres, insulin resistance, fat infiltration, fibrosis, disrupted aerobic capacity and neurological derangements[12]. The evaluation of muscle quality is more challenging however. Suggestions have been made to measure the pennation angle (PA), fascicle length (FL), echo intensity (EI), muscle elastography (ME), phase angle (PhA) and muscle density (MD)[6]. The latter is defined as the mean attenuation coefficient, expressed in Hounsfield Units (HU), measuring muscular fat infiltration[13]. Skeletal muscle gauge (SMG)

Search Strategy: Medline via Ovid, last search April 11th 2023
1 Ultrasonography/ (199091)
2 echotomograph*.ti,ab,kf. (761)
3 ultrasound*.ti,ab,kf. (309414)
4 ultrasonograph*.ti,ab,kf. (127003)
5 (ultrasonic adj2 (diagnos* or imaging or tomograph*)).ti,ab,kf. (4291)
6 echograph*.ti,ab,kf. (10275)
7 echotomograph*.ti,ab,kf. (761)
8 sonograph.ti,ab,kf. (76)
9 Tomography, X-Ray Computed/ (416021)
10 ((xray or x-ray) adj3 (tomograph* or ct or scan*)).ti,ab,kf. (31561)
11 tomodensitometr*.ti,ab,kf. (1230)
12 Magnetic Resonance Imaging/ (469570)
13 (mri* adj2 (functional or scan*)).ti,ab,kf. (43199)
14 "chemical shift imaging*".ti,ab,kf. (1105)
15 "magnetic resonance imaging*".ti,ab,kf. (292219)
16 ((imaging* or tomography) adj2 (echo or chemical or nmr)).ti,ab,kf. (10793)
17 or/1-16 (1392522)
18 (pennation adj2 (muscle* or angle*)).ti,ab,kf. (854)
19 (muscle adj2 (fiber or fibre) adj2 (angle or length)).ti,ab,kf. (309)
20 (muscle adj2 (brightness or thickness or density)).ti,ab,kf. (5140)
21 (muscle adj4 (echo-intensity or echointensity or echo intensity)).ti,ab,kf. (311)
22 (muscle adj2 (cross-sectional or surface or cross sectional) adj2 area).ti,ab,kf. (2514)
23 (fascicle adj2 (angle or rotation or length)).ti,ab,kf. (915)
24 or/18-23 (8753)
25 17 and 24 (4091)
26 exp animals/ not humans.sh. (5110748)
27 (exp infant/ or exp child/ or adolescent/) not exp adult/ (2121700)
28 25 not 26 not 27 (3669)
29 limit 28 to English language (3620) 30 limit 29 to dt=20210901-20230411 (605)

Table 1. Search strategy.

is a less frequently computed muscle parameter that is calculated by multiplying the SMI and the MD[14].

Sarcopenia is prevalent, especially in older individuals, with prevalence varying from 10 to 27% in older persons, depending on the definition and cut-off values used. However, muscles of younger individuals aged <60 years can also be affected, with prevalence ranging from 8 to 36%[15]. Muscle status is an important parameter for general health. It is already known that sarcopenia confers higher mortality rates, more functional decline, higher risk of falling and an increased risk of hospitalization[16]. Sarcopenia and oncological problems often co-exist, and the combination is associated with higher prevalence of adverse outcomes. In oncological treatment, decisions are often made considering chronological age. However, sarcopenia is associated with poorer prognosis and more postoperative complications in oncology patients. This is due to a combination of primary and secondary sarcopenia. Sarcopenic patients with cancer suffer from more pulmonary complications, infections, higher readmission rates and increased length of hospitalization[17]. A higher treatment toxicity and a reduced quality of life are also seen[18].

The aim of this study was twofolded. First, to review which muscle parameters were associated to certain clinical outcomes in oncology, such as: overall survival, progression-free survival, cancer-specific survival, chemotoxicity, surgical outcomes, response to oncologic treatment, length of stay and rehospitalisation, and quality of life. Second, we wanted to give an insight in the current literature about muscle status and oncological outcomes, so that an impetus can be given for a more routine geriatric assessment and follow-up when considering oncologic treatments.

Methods

This systematic review is part of a series of systematic reviews considering clinical health outcomes and muscle parameters which will be published separately, and are part of Sarcopenia through Ultrasound (SARCUS), a larger European non-funded academic project initiated in 2016, which involves researchers in different institutions in different countries, and has been gathered under the auspices of the European Union Geriatric Medicine Society (EuGMS) and the University of Antwerp, Belgium. This manuscript presents the efforts of the SARCUS project in gathering knowledge about the different outcomes in Oncology.

The combined systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (19). The protocol was registered in the Prospective Register of Systematic Reviews Database (PROSPERO) under the registration number CRD42020179671. In this protocol, numerous clinical outcomes were investigated

Study Characteristic	N (TOTAL = 117)
Type of Study	
Original Article	117
Retrospective	98
Prospective	19
Subject of Study	
Survival	96
Chemotoxicity	20
Outcomes After Surgery	33
Response To Treatment	12
Duration of Hospitalization and Rate of Readmission	20
Quality of Life	3
Radiographic Method	
CT	102
MRI	14
US	3
BIA	3
DXA	1
More Than 1	4
Muscle Parameter Investigated	
SMI	74
MD	54
CSA	23
MT	14
SMG	6
SMM	1
PMI	8
EI	1

BIA = bioelectrical impedance analysis; CSA = cross-sectional area; CT = computed tomography; DXA = dual-energy X-ray absorptiometry; EI = echo intensity; MD = muscle density; MRI = magnetic resonance imaging; MT = muscle thickness; PMI = psoas muscle index; SMG = skeletal muscle gauge; SMI = skeletal muscle index; SMM = skeletal muscle mass; US = ultrasound.

Table 2. General study characteristics.

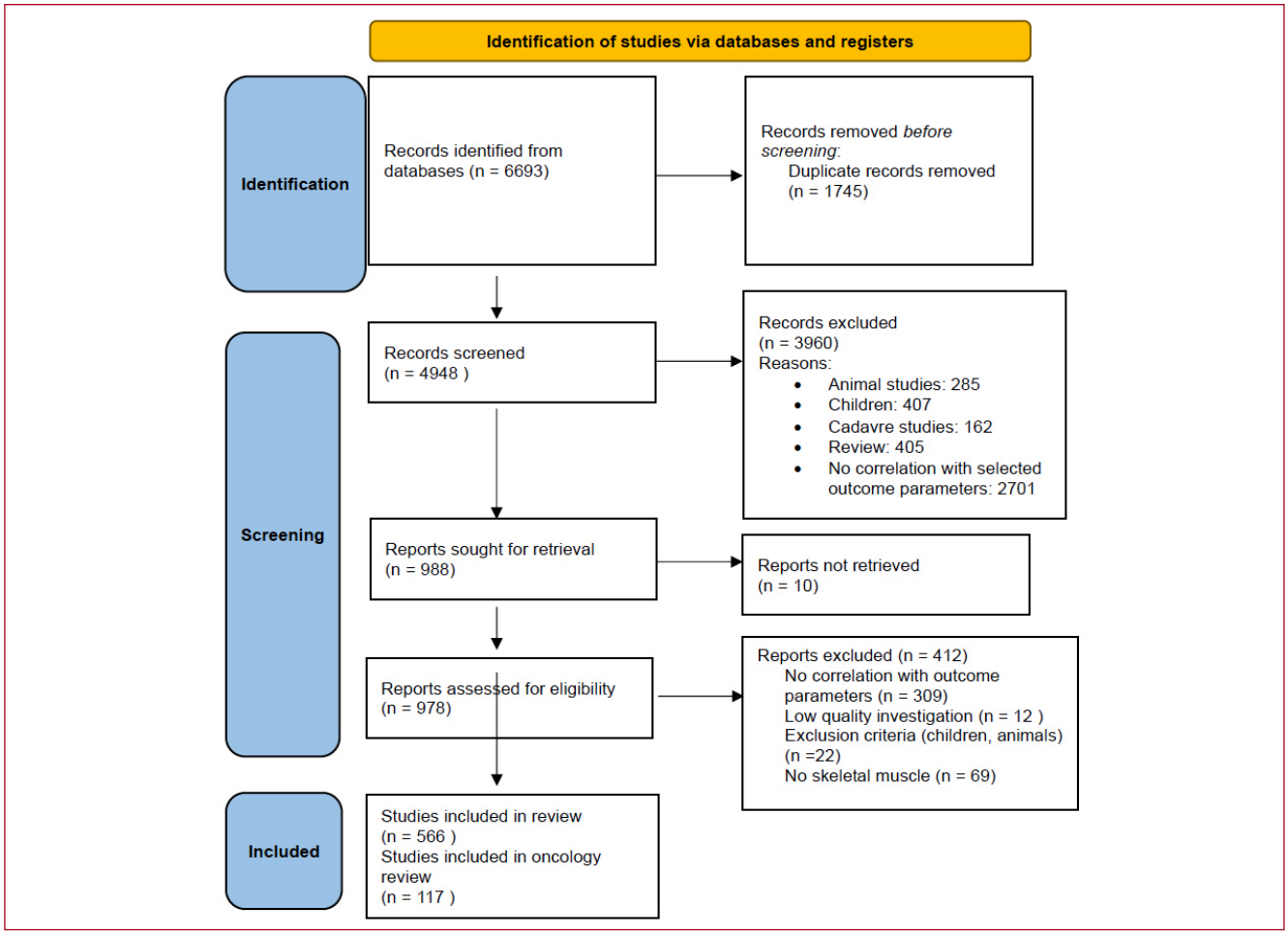

Figure 1. PRISMA flow diagram.

in association with macroscopic muscle parameters (such as oncological, surgical, medical, survival, length of stay, mobility, frailty, nutritional, bone health, respiratory, masticulatory, functionality, dysphagia, ...). Later, these results were divided into different articles with focus on one specific outcome parameter.

Inclusion and exclusion criteria

The following keywords and their related MESH terms were used for the search (see Table 1 for the complete search terms): Ultrasound, Computed Tomography, Magnetic Resonance Imaging, Pennation angle, Muscle thickness, Echo-intensity, Muscle density, Cross-sectional area, Fascicle length. In the first article selection, all possible clinical outcomes were included. Exclusion criteria were studies involving children, animals or cadaver studies, review studies and case reports. Only articles in English were included in the study according to existing literature[20,21].

Search strategy and article selection

An initial search was performed on April 14th 2020. Because numerous new articles were published in the time of data extraction and analysis, follow-up searches were conducted on September 29th 2021 and April 11th 2023 to check for the latest published research to improve the quality of the paper. Systematic searches were performed using SCOPUS, AMED and EBM Reviews - ACP Journal Club. Duplicates were removed and titles and abstracts were selected for eligibility by two investigators (SB and SP) using Rayyan software. In case of disagreement about in- or exclusion, the article was included. Then, the full text articles were sought through different libraries or through contacting the authors via Researchgate. Subsequently, the articles were subdivided among the authors for further selection and data extraction. Each full text article was checked on suitability for the study by SB and one other reviewer out of 18 different researchers, and data extraction was performed by both reviewers.

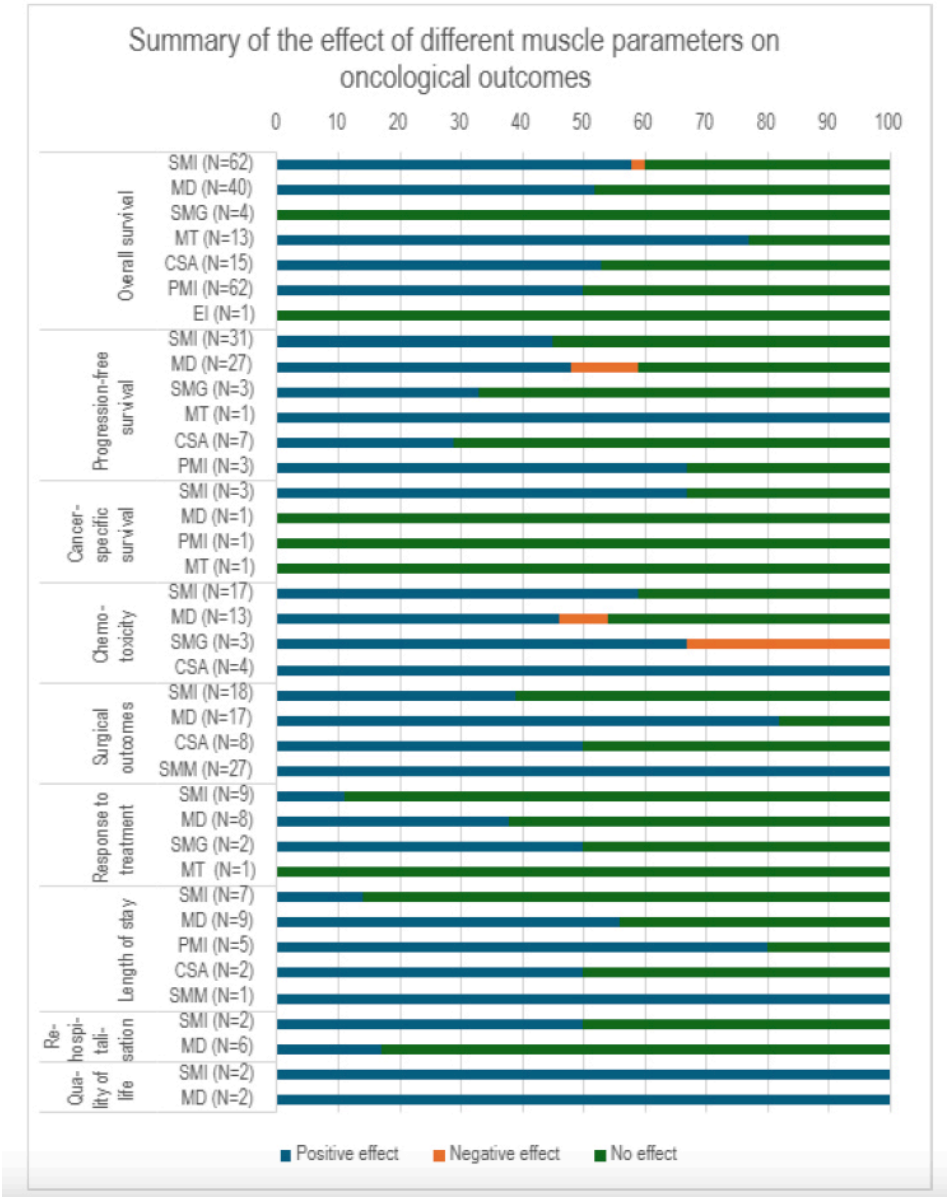

Figure 2. Summary of the effect of different muscle parameters on oncological outcomes. *(Abbreviations: CSA = cross-sectional area; EI = echo intensity; MD = muscle density; MT = muscle thickness; PMI = psoas muscle index; SMG = skeletal muscle gauge; SMI = skeletal muscle index).*

Data extraction and analysis

Data were extracted by 18 different researchers, and checked personally by SB. Disagreement was solved through intensive discussion. The extracted data included author, year of publication and country of investigation, population of interest (with gender and mean age), examined muscle or muscle group, imaging technique, muscle parameter, the investigated outcome measure, and the findings.

Results of the analysis on oncological outcomes were subdivided into six categories: survival, chemotoxicity, postoperative outcomes, response to treatment, duration of hospitalization and quality of life. Since survival can be defined in different ways, the differentiation was made between overall survival, progression-free survival, and cancer-specific survival.

Results

Study selection

A total of 6693 articles were identified after the last search for the combined health outcomes. After eliminating duplicates, the study yielded 4948 unique articles. After title and abstract selection, 988 studies remained. Full text articles were found in 978 cases for the total health study for article selection and quality assessment. 10 articles could not be found, either because no full text was available in the English language, or because they could not be retrieved on the different libraries or through Researchgate. Of these, 566 articles were eventually considered suitable for data extraction of all outcome parameters. For the review focused on oncological outcomes, 117 of 566 articles were included. The overview of study selection can be found in Figure 1. Table 2 shows the general study characteristics of the included articles. Table 3 indicates the different investigated primary tumor locations. An overview of the included articles is shown in Tables 4-9.

General study characteristics

All of the included articles were original studies. Ninety-eight had a retrospective set-up and 19 were prospective. Ninety-six had data on survival. Twenty articles contained information on chemotoxicity and 33 on outcomes after oncological surgery. Twelve articles involved the response to the oncologic treatment. The duration of hospitalization and the rate of readmission was described in 20 articles. Finally, three articles highlighted the association of muscle parameters with the quality of life in patients suffering from cancer.

Most included studies measured muscle parameters by CT (102 articles). The remainder of the studies used MRI (14 studies), US (3 studies), BIA (3 studies) or DXA (1 study). Four articles included more than one measurement method. Most studies described the effect of skeletal muscle index (SMI, a quantitative measure) and muscle density (MD, a qualitative measure) on oncologic outcomes. In the great majority of these studies, SMI was calculated by CT as the CSA or all muscle tissue at the level of L3, divided by the square of height (cm^2/m^2). However, few studies used the CSA of all muscles at L4 or T12 divided by the square of height, or used DEXA or BIA to define SMI (by appendicular skeletal muscle mass divided by the square of height). Most, but not all studies used the cut-off values for SMI as stated by Martin et al. CSA, MT, and SMG are other muscle parameters used in the included studies. All results with positive, negative or no effect are summarized in Figure 2.

Oncology and survival

Ninety-six articles studied the effect of radiographic muscle parameters on survival. An overview of all the included articles can be found in Table 4[22-115].

Tumor Location	Number of Included Studies
Pulmonary	16
Lower Gastro-Intestinal	14
Hematological	12
Urogenital	12
Head/Neck	9
Neurological	8
Liver/Bile	8
Upper Gastro-Intestinal	7
Breast	7
Pancreas	3
Ovarium	3
Melanoma	3
Endometrial	2
Sarcoma	2
Different/Not Stated	9

Table 3. Overview of the tumor locations in the included studies.

Overall survival

Overall survival (OS) was the most commonly used parameter used in survival analysis. It is defined as the time from randomization in the study until death. Ninety studies investigated the effect of muscle parameters on OS.

Sixty-two studies investigated the impact of skeletal muscle index (SMI) as measured by CT. An association between higher SMI and improved overall survival was seen in 36/62 (58%), with hazard ratios (HR) reported in 31 of these ranging from 1.22 to 4.9 (median 2.1). In 25/62 (40%) no significant association of SMI on overall survival was seen. One article revealed conflicting results favouring low SMI, with HR of 0.19. The authors attributed this to the high number of women in their population.

Forty articles described the association of muscle density by CT with OS. Higher MD was associated with better survival in 21/40 (52%), with HR for low MD ranging from 1.11 to 4.02 (median 2.01). In 19/40 (48%), no significant impact of MD could be found.

Although SMG is calculated from SMI and MD, the four articles that investigated SMG did not significantly show an effect on OS. MT showed a beneficial association between greater MT and OS in 10/13 (77%) studies, with HR ranging from 1.23 to 10.79 (median 2.13). The studies on MT mostly used MRI, but one article described the use of US. CSA was measured by CT in 13 articles, and by MRI in two. In 8/15 (53%) of the studies higher CSAs were

Table 4. Characteristics and results of included studies on survival in oncology.

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Abbass, 2020, UK[22]	R	643 advanced lung cancer patients (51.3%, 70y)	10 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.22* o Multivariate: HR 1.17 • Low MD: o Univariate: HR 1.11
Abe, 2018, Japan[23]	R	87 metastatic urothelial cell carcinoma patients treated with systemic chemotherapy (74.7%, 73)	15.4 months	L3	SMI (CT)	OS	• Low SMI: o Multivariate (stratified for BMI): HR 3.1**
Akce, 2021, USA[24]	R	57 advanced HCC patients treated with immunotherapy (77.2%, 66)	6 months	L3	SMI (CT)	OS	• Low SMI: o OS 5 vs. 14.3 months o Multivariate: HR 1.71
						PFS	• Low SMI: o Multivariate: 0.99
Al Khaldi, 2022, Canada[25]	R	312 patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy for peritoneal metastases (34.3%, 57.6)	28 months	L3	SMI (CT)	OS	• Low SMI: o Multivariate: HR 1.17
Antoun, 2013, France[26]	P	149 renal cell carcinoma patients treated with Sunitinib, Sorafenib or Everolimus (76%, 58)	Not stated	L3	CSA (CT) MD (CT)	OS	• Low MD below median: o Univariate: HR 2** o Multivariate: HR 1.9** • CSA: No significant association
						PFS	• MD < median: o Univariate: HR 1.9** o Multivariate: HR 2** • CSA: No significant association
Arayne, 2023, Australia[27]	R	80 patients with stage I – III rectal cancer undergoing curative resection (74%, 63)	Not stated	T4, T12, L3	SMI (CT)	OS	• Low SMI = higher mortality: o T4: 45 vs.5%** o For T12: 45 vs.10%* o For L3: 45 vs.10%*
Arien, 2020, Belgium[28]	R	180 older adults with cancer (48%, 80)	Not stated	Left psoas mid-L3	CSA (CT) MD (CT)	OS	• Low MD: o Univariate: HR 1.04 • Low CSA: o Univariate: HR 1.52*
Asai, 2023, Japan[29]	R	456 patients undergoing major hepatectomy for perihilar cholangiocarcinoma (68%, 69)	Not stated	Psoas at L3	MD (CT) PMI (CT)	OS	• Lowest tertile PMI: o OS 37.8 versus 54.2 months. • Lowest tertile MD: NS
Bardoscia, 2022, Italy[30]	R	225 head and neck cancer patients undergoing radiation or chemoradiation (75.6%, 64.5)	5.6 year	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.19 o Multivariate: HR 0.86 • Low MD: o Univariate: HR 2.12** o Multivariate: HR 1.88* (age, sex, stage, DM, BMI and weight loss)
						PFS	• Low SMI: o Univariate: HR 1.18 o Multivariate: HR 0.84 • Low MD: o Univariate: HR 2.37** o Multivariate: HR 2.26 (age, sex, stage, DM, BMI and weight loss)

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
						CSS	• Low SMI: o Univariate: HR 1.25 o Multivariate: HR 0.94 • Low MD: o Univariate: HR 2.46* o Multivariate: HR 2.40* (age, sex, stage, DM, BMI, weight loss)
Begini, 2017, Italy[31]	R	92 cirrhosis patients with HCC (70.6%, 71.6)	Not stated	L3	SMI (CT)	OS	• Sarcopenia (low SMI): o Univariate: HR 2.20** o Multivariate: HR 2.37 (BCLC, TNM, Child-Pugh, bilirubin, performance status)
Besutti, 2021, Italy[32]	R	116 diffuse large B-cell lymphoma patients (51.7%, 63.7)	30 months	L3 Proximal thigh (PT)	SMI (CT) MD (CT)	OS	• Low L3 SMI (continuous) o Univariate: HR 0.81 o Multivariate: HR 0.48* (IPI, sex, BMI, and therapy) • Low PT SMI (continuous): o Univariate: HR 1.18 o Multivariate: HR 0.98 • Low L3 MD (continuous): o Univariate: HR 2.17 o Multivariate: HR 1.69 • Low PT MD (continuous): o Univariate: HR 2.57** o Multivariate: HR 2.17** (IPI, sex, BMI, and therapy)
						PFS	• Low L3 SMI (continuous) o Univariate: HR 1.04 o Multivariate: HR 0.86 • Low PT SMI (continuous): o Univariate: HR 1.16* o Multivariate: HR 1 • Low L3 MD (continuous): o Univariate: HR 1.56* o Multivariate: HR 2.27 • Low PT MD (continuous): o Univariate: HR 2.44** o Multivariate: HR 1.61
Bronger, 2017, Germany[33]	R	128 patients with advanced serous ovarian cancer (65)	117 weeks	L3	SMI (CT)	OS	• Low SMI (sarcopenia): o Lower OS: 23 vs.48 months o Univariate: HR 3.17* o Multivariate: HR 2.89* (age, residual tumor)
						PFS	• Low SMI (sarcopenia): o Lower PFS: 15 vs.22 months o Univariate: HR 2.64* o Multivariate: HR 2.52* (age, residual tumor, FIGO)
Chakedis, 2018, USA[34]	R	177 patients with biliary tract cancer (44%, 66)	12.2 months	L3 Psoas	PMI (CT) MD (CT)	OS	• Low PMI (sarcopenia): o Lower OS: 12.6 vs.38.7 months** o Higher 1-year mortality: 40 vs.21% o Univariate: HR 2.33** o Multivariate: HR 3.52** (age, sex, ethnicity, mFI category, pathology diagnosis, NLR) • Low MD: o Univariate: HR 2.10* o Multivariate: HR 2.96*
						PFS	• Low PMI (sarcopenia): o Higher mortality: 71 vs. 40%**

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Charette, 2019, Belgium[35]	P	217 chemorefractory advanced colorectal cancer patients (57%, 63)	Not stated	L3	MD (CT) SMI (CT)	OS	• Low SMI: o Univariate: HR 2.06* o Multivariate: HR 1.49** (age, BMI, sex, performance status, time since diagnosis, low SMI, low MD, low SC fat index, high SC fat density, low visceral fat index, high visceral fat density) • Low MD: o Univariate: HR 1.54* o Multivariate: HR 1.80** (age, BMI, sex, performance status, time since diagnosis, low SMI, low MD, low SC fat index, high SC fat density, low visceral fat index, high visceral fat density) • Best cut-offs for association with survival: SMI 47.5 cm^2/m^2, MD 22.5HU
Cho, 2022, Austria[36]	R	566 patients with brain metastases from NSCLC (48%, 63)	Not stated	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Low MT (≤6.3mm in men and ≤ 5.2 mm in women): o Univariate: HR 1.90** o Multivariate: HR 1.68** (age groups, sex, number of brain metastases, presence of ECMs, NSCLC subtype, KPS groups, RPA classes, and concomitant IT or TT) o Shorter survival: 7.5 vs.18.6 months
Chu, 2017, Canada[160]	R	224 DLBCL patients treated with Rituximab-containing therapy (56%, 62)	Not stated	L3	MD (CT) SMI (CT)	OS	• Low SMI: o Univariate: HR 0.77 • Low MD: o Univariate: HR 3.45** o Multivariate: HR 2.52** (R-IPI scores and gender)
						PFS	• Low SMI: o Univariate: HR 0.65 • Low MD: o Univariate: HR 2.28** o Multivariate: HR 3.76 (R-IPI and gender)
Chu, 2015, Canada[37]	R	145 follicular lymphoma patients who received chemoimmunotherapy (55%, 59)	Not stated	L3	MD (CT) SMI (CT)	OS	• Low SMI: o Univariate: HR 1.06 • Low MD: o Univariate: HR 4.02** o Multivariate: HR 3.40 (FLIPI-1 scores and gender)
						PFS	• Low SMI: o Univariate: HR 0.65 • Low MD: o Univariate: HR 1.85* o Multivariate: HR 1.65 (FLIPI-1 scores and gender)
Chu, 2020, Canada[38]	R	97 metastatic melanoma patients treated with Ipilimumab (60%, 56)	Not stated	L3	MD (CT) SMI (CT)	OS	• Low SMI (sarcopenia) o Multivariate: HR 2.46** (gender, LDH, line of therapy, BRAF) • Low MD: • Univariate: HR 2.47** Multivariate: HR 2.12* (gender, LDH, line of therapy, BRAF)
						PFS	• Low SMI (sarcopenia) o Multivariate: HR 1.85* (gender, LDH, line of therapy, BRAF) • Low MD: • Univariate: HR 1.77** • Multivariate: HR 1.55 (gender, LDH, line of therapy, BRAF)
Cinar, 2022, Turkey[39]	R	180 patients undergoing resection for NSCLC (80%, 65)	26.3 months	T12 paravertebral muscles	PVMI (CT) MD (CT)	OS	• Low PVMI: o Lower survival: 52.5 vs. 57.5 months** o Univariate: HR 2.10** o Multivariate: HR 1.77** • Low MD: o Lower survival: 50.8 vs.59.4 months** o Univariate: HR 2.71** o Multivariate: HR 1.84

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Cortellini, 2020, Italy[161]	R	100 patients with advanced cancer receiving anti-PD-1/PD-L1 checkpoint inhibitors (67%, 66)	20.3 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 2.19** o Multivariate: HR 2.19** o Melanoma subgroup: HR 3.11* • Low MD: o Univariate: HR 1.15
						PFS	• Low SMI: o Univariate: HR 1.66* o Multivariate: HR 1.48 • Low MD: o Univariate: HR 1.09
Cushen, 2014, Ireland[41]	R	55 metastatic renal cell carcinoma treated with Sunitinib (78%, 66)	6 months + until drug was stopped	L3 (all muscles)	SMI (CT)	PFS	• No difference in low vs. high SMI group
DeFilipp, 2018, USA[42]	R	218 lymphoma patients who received high-dose chemotherapy and auto-HCT (59%, 56) and 97 who received allo-HCT (60%, 53)	Not stated	L3 (all muscles)	SMI (CT)	OS	• Low SMI-based sarcopenia: o Univariate: HR 1.63*
Dijksterhuis, 2019, the Netherlands[43]	R	88 advanced esophagogastric cancer patients treated with 1st line CapOx (75%, 63)	Not stated	L3 (all muscles)	SMI (CT) MD (CT)	OS	• Low SMI pre-treatment: o Univariate: HR 0.70 o Multivariate: HR 0.94 • Low MD pre-treatment: o Univariate: HR 0.94 o Multivariate: HR 1.40
						PFS	• Low SMI pre-treatment: o Univariate: HR 0.72 o Multivariate: HR 0.78 o After 3 cycles: HR 0.56* • Low MD pre-treatment: o Univariate: HR 1.04 o Multivariate: HR 1.05
Ferraro, 2022, Germany[44]	R	72 patients with primary central nervous system lymphoma (51%, 68)	At least 2 years or until death	L3 (all muscles)	SMI (CT) MD (CT) SMG (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 0.61 • Low MD pre-treatment: o Univariate: HR 0.97* o Multivariate: HR 0.98 (age and gender)
						PFS	• Low SMI (sarcopenia): o Univariate: HR 0.65
Furtner, 2021, Austria[45]	R	128 patients with CNS lymphoma (52%, 62.7)	Not stated	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Low MT (sarcopenia): o Univariate: HR 3.19* o Multivariate: HR 2.50** (gender, age, deep brain involvement, ECOG, and MTX-based therapy)
Ganju, 2019, USA[162]	R	46 stage Ib-IVa patients with endometrial cancer treated with hysterectomy and pelvic radiation (0%, 51)	27 months	L3	SMI (CT) MD (CT)	OS	• Low SMI (sarcopenia): o Univariate: 2.42 • Low MD: o Univariate: 3.52 • Low SMI + low MD: o Univariate: HR 4.25**

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Golder, 2022, UK[47]	R	1146 patients with colon cancer (51%, age not stated)	Minimum 4 years	L3 (all muscles)	SMI (CT) MD (CT)	OS	• Stage III: o SMI and 3-year OS: NS o Low MD = worse 3-year OS: 76 vs. 75%* • Stage IV: o Low SMI = worse 3-year OS: 43 vs. 16%** o Low MD: NS
Haehl, 2022, Germany[48]	R	280 head and neck squamous cell carcinoma patients receiving curative (chemo)radiation (gender not stated, age >65)	127 days	C3 (perivertebral + SCM) L3 (calculated from C3)	SMI (CT) CSA (CT)	OS	• Low SMI: o OS 26 vs. 47 months* o 2-year survival 51.0 vs.68.0%* o Univariate: HR 1.55* o Continuous: HR 1.33* o Low CSA (sarcopenia): o OS 23 vs. 91 months** o 2-year survival 49.6 vs.71.1%** o Univariate: HR 1.79** o Multivariate: HR 1.64* (age, smoking status and Karnofsky Index) o Continuous: HR 1.56**
Hirai, 2020, Japan[49]	R	163 soft tissue sarcoma patients (59.5%, 64.2)	27 months	L3	SMI (CT) MD (CT) SMG (CT)	OS	• No impact of SMI, MD, or SMG on 5-year survival
Huang, 2021, China[51]	P	587 patients with BMI >23 kg/m^2) who underwent radical gastrectomy for gastric cancer (74%, 65)	43.8 months	L3	MD (CT)	OS	• Low MD + GLIM-defined malnutrition: HR 2.15** • GLIM-defined malnutrition alone: HR 2.24*
						PFS	• Low MD + GLIM-defined malnutrition: HR 1.99** • GLIM-defined malnutrition alone: HR 1.97**
Huang, 2021, China[50]	P	597 older patients (aged 65 years) who underwent radical gastrectomy for gastric cancer (77%, 72)	33.5 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.525** o Multivariate: HR 0.933 • Low MD: o Univariate: HR 1.497* o Multivariate: HR 1.24
						PFS	• Low SMI: o Univariate: HR 1.459* o Multivariate: HR 0.937 • Low MD: o Univariate: HR 1.501* o Multivariate: 1.24
Huq, 2021, USA[52]	R	384 patients undergoing surgery for glioblastoma (41%, 57.8)	Not stated	Temporalis muscle	MT (MRI)	Post-operative survival	• High MT: o Multivariate in progressive glioblastoma: HR 2.13* o Multivariate in primary glioblastoma: HR 0.99
Jeon, 2021, South Korea[53]	R	479 breast cancer patients who underwent surgery and adjuvant chemotherapy (0%, 51)	79 months	L3	SMI (CT) MD (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 1.22 • Low MD: o Univariate: HR 0.65
						CSS	• Low SMI (sarcopenia): o Univariate: HR 1.35 • Low MD: o Univariate: HR 1.07
Kim, 2015, South Korea[54]	R	149 newly diagnosed, pathologically proven SCLC patients (85.2%, 68.6)	29 months	L3	SMI (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 1.66* o Multivariate: HR 1.68* (age, extensive stage, ECOG-PS>2, supportive care only, sarcopenia, and LDH)

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Kim, 2021, South Korea[55]	R	330 pancreatic cancer patients undergoing chemotherapy (49%, 63.4)	Not stated	L3	MD (CT) SMI (CT)	OS	• Low SMI: o Univariate: HR 1.52* o Multivariate: HR 1.53* • Low MD: o Multivariate: HR 1.45* • Low MD + low SMI: HR 1.58*
Kim, 2022, Korea[56]	R	221 NSCLC patients with brain metastasis (60%, 65)	5 months	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Lower MT: o Multivariate: HR 1.37* (gender, age, ECOG) o Lower survival: 4.0 vs. 7.0 months*
Kuroki, 2015, USA[57]	R	122 endometrial cancer patients (0%, 65.9)	Not stated	Psoas L3	CSA (CT)	OS	• Low CSA (sarcopenia): o Univariate: HR 1.57 o Multivariate: HR 1.98
						PFS	• Low CSA (sarcopenia): o Shorter PFS: 23.5 vs.32.1 months* o Multivariate: HR 3.99* (race, BMI, lymphocyte count, and tumor histology)
Lanza, 2020, Italy[58]	R	142 HCC who received bland transarterial embolization (77%, 73)	27 months	L3	SMI (CT)	OS	• Low SMI (sarcopenia): o Multivariate: HR 2.22*
Lee, 2018, South Korea[59]	R	140 advanced gastric cancer patients (76%, 67)	31.9 months	L3	SMI (CT)	OS	• Low SMI: o Univariate: HR 1.47* o Multivariate: HR 1.51* (no response on chemotherapy, no second line, >3 metastatic sites, albumin <3.5)
Leone, 2021, Italy[60]	R	43 patients with primary central nervous system lymphoma (35%, 61)	23 months	L3 Temporal muscle	SMI (DXA) MT (MRI)	OS	• L3-SMI < sex-specific cut-off: HR 3.27* • Low L3-SMI: o Univariate: HR 3.27* o Multivariate: HR 3.16* • Low TMT < sex-specific cut-off: o Univariate: HR 4.61 o Multivariate: HR 4.94**
						PFS	• L3-SMI < sex-specific cut-off: HR 4.42** • Low L3-SMI: o Univariate: HR 4.42* o Multivariate: HR 4.40** • Low TMT < sex-specific cut-off: o Univariate: HR 4.57** o Multivariate: HR 4.39**
Li, 2021, China[61]	R	192 treatment-naïve intermediate-stage HCC patients undergoing TACE (82%, 60)	21.3 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.02 • Low MD: o Multivariate: HR 1.01
						PFS	• Low SMI: o Univariate: HR 1.01 • Low MD: o Multivariate: HR 1.02
Liu, 2020, China[62]	R	130 patients with primary glioblastoma (62.3%, 61.5)	Not stated	Temporal muscle	MT (MRI)	OS	• MT < median: o Univariate: HR 1.25** o Multivariate: HR 0.86* (age, concurrent chemoradiotherapy)
Looijaard, 2019, the Netherlands[63]	R	378 colorectal cancer patients (60.3, 73.4)	5.3 years	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.05 • Low MD: o Univariate: 1.23*

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Loumaye, 2017, Belgium[64]	P	149 patients treated for colorectal or lung cancer (57%, 67)	24 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.96* o Multivariate: HR 3.63** (lung cancer, ECOG, activin A, albumin) • Low MD <30 HU: o Univariate: HR 2.01*
Martin, 2020, Germany[65]	R	114 anal carcinoma patients treated with 5-FU or MMC (51%, 58.5)	30 months	L4	SMI (CT)	OS	• Low SMI: o Univariate: HR 1.94 o Multivariate: HR 0.78
						PFS	• Low SMI: o Univariate: HR 1.01 o Multivariate: HR 0.97
Maurits, 2022, the Netherlands[66]	R	719 stage I-III renal cell cancer patients (61%, 64) 320 stage IV renal cell cancer patients (64%, 66.5)	6.35 years	L3	SMI (CT) MD (CT)	OS	• Stage I-III: o SMI per 10 cm^2/m^2 decrease: NS o MD per 10 HU decrease: HR 1.45* in women • Stage IV: o SMI per 10 cm^2/m^2 decrease: NS o MD per 10 HU decrease: HR 1.35* in men • Low SMI: o Univariate: HR 1.45* o Multivariate: HR 1.20 • Low SMI: o Univariate: HR 1.89* o Multivariate: HR 1.19
						PFS	• Stage I-III: o SMI per 10 cm^2/m^2 decrease: HR 2.01* o MD per 10 cm^2/m^2 decrease: NS
McGoldrick, 2022, UK[67]	R	111 older adults with squamous cell carcinoma of the head and neck (69%, 74)	26-60 months	Masseter 2cm below the zygomatic arch	CSA (CT)	OS	• Low CSA (sarcopenia) o Univariate: HR 1.74* o Multivariate: HR 1.65
Mi, 2022, UK[68]	R	96 glioblastoma patients (70%, 57)	19.2 months	Temporal muscle between mid-orbital and orbital roof	CSA (MRI)	OS	• Low CSA: o Univariate: HR 2.27* o Multivariate: HR 2.16* (age and gender)
						PFS	• Low CSA: o Univariate: HR 2.27* o Multivariate: HR 2.32* (age and gender)
Miller, 2012, USA[69]	R	125 adrenocortical carcinoma patients (40.8%, 45.7)	2.0 years	L4 psoas	MD (CT) PMA (CT)	OS	• PMA per 100 mm^2 decrease: HR 1.09* • Predictors of survival: MD**, PMA**
Miyamoto, 2018, Japan[70]	R	52 metastatic colorectal cancer patients (62%, 67)	4 months	L3	SMI (CT)	OS	• Low SMI: o Shorter OS: 3.7 vs. 7.3 months** o Univariate: HR 2.872** Multivariate: HR 2.381* (EOCG 2 and obesity)
						PFS	• Low SMI: o Shorter PFS: 1.9 vs. 2.8 months**
Muglia, 2020, Italy[71]	R	51 glioblastoma patients (72.6%, 57)	Not stated	Temporalis muscle	MT (MRI)	OS	• Low MT: o Univariate: HR 1.34
Munoz-Rodríguez, 2021, Spain[72]	R	59 metastatic prostate cancer patients who received androgen deprivation therapy (100%, 72.5)	30.5 months	Psoas	MD (CT)	OS	• Low MD: o Univariate: HR 1.11** o Multivariate: HR 1.10** (bone metastases, visceral metastases, no testosterone escape)

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Nishikawa, 2018, Japan[73]	R	85 head and neck squamous cell carcinoma patients (78%, 66)	888 days	L3	SMI (CT)	OS	• Low SMI: o Univariate: HR 3.4** o Multivariate: HR 3.5* (pre-treatment weight loss, albumin, and CRP)
Nishioka, 2020, Japan[74]	R	156 NSCLC patients receiving immunotherapy (65%, 67)	Not stated	L3	MD (CT) SMI (CT)	OS	• Low SMI: o Univariate: NS • Low MD: o Univariate: NS
						PFS	• Low SMI: o No difference in PFS • Low MD: o Lower PFS: 2 vs. 4.5 months*
Nozawa, 2020, Japan[75]	R	98 stage IV unresectable colorectal cancer patients who received systemic therapy (59%, 64)	44.3 months	L3	SMI (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 3.22* • Multivariate: HR 4.0* (age, CCI, lung metastasis, postoperative chemotherapy)
						PFS	• Change in SMI: NS
Omarini, 2019, Italy[76]	R	137 breast cancer patients (stage I–III) treated with primary chemotherapy (0%, 50)	Not stated	L3	CSA (CT) SMI (CT)	OS	• No significant correlation with CSA or SMI
						PFS	• No significant correlation with CSA or SMI
Ozeki, 2020, Japan[77]	R	165 squamous cell type lung carcinoma patients (88%, 69.6) + 556 adeno-type lung carcinoma patients (57%, 38.1)	61 months	Psoas bilateral	PMI (CT)	OS	• Low PMI: o Multivariate for SCC: HR 2.0** o Multivariate for ADC: HR 1.03
						PFS	• Low PMI: o Multivariate for SCC HR 1.78** o Multivariate for ADC: HR 1.02
Özer, 2022, Turkey[78]	R	66 glioblastoma patients (58%, 57)	14.0 months	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Low TMT: o Multivariate: HR 10.786*
Peng, 2020, Taiwan[79]	R	116 pancreatic adenocarcinoma with pancreatico-duodenectomy patients (58.6%, 66.2)	Not stated	L3	SMI (CT) MD (CT)	OS	• Low SMI (Sarcopenia): o Univariate: HR 2.34* o Multivariate: HR 2.51* (age, gender, preoperative sarcopenia, sarcopenic obesity, diabetes, tumor size, stage, grade, lymphogenic invasion, resection margin) o Sarcopenic obesity: HR 3.19* o SMI continuous: NS • Low MD: o Univariate HR 1.28 o Continuous: NS
						PFS	• Low SMI (Sarcopenia): o Univariate: HR 1.0 • Low MD: o Univariate: HR 1.11
Pereira, 2021, Brazil[80]	P	50 hematologic cancer patients admitted for autologous and allogeneic HSCT (58%, 49)	Not stated	QF	MT (US) EI (US)	OS	• 100-day mortality not correlated with MT or EI
Phan, 2020, USA[81]	R	89 soft tissue sarcoma patients (60%, 58.5)	Not stated	T12	MD (CT) SMI (CT)	OS	• Low SMI: o Univariate: HR 0.92 o Multivariate: HR 0.79 • Low MD: o Univariate: HR 1.64** o Multivariate: 0.65*
						PFS	• Low SMI: o Univariate: HR 1.28 o Multivariate: HR 1.35 • Low MD: o Univariate: HR 1.47* o Multivariate: HR 1.47

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Rier, 2020, the Netherlands[82]	R	164 diffuse large B-cell lymphoma patients (49%, 64.5)	57 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.24 o Multivariate: HR 1.16 • Low MD: o Univariate: HR 2.05* o Multivariate: HR 1.68 • Low MD + Low SMI: o Univariate: HR 2.74** o Multivariate: HR 2.42* (age, gender, BMI, IPI)
						PFS	• Low SMI: o Univariate: HR 1.26 o Multivariate: HR 1.19 • Low MD: o Univariate: HR 1.74 o Multivariate: HR 1.43 • Low MD + Low SMI: o Univariate: HR 2.48** o Multivariate: HR 2.16* (age, gender, BMI, IPI)
Rutten, 2017, the Netherlands[83]	R	216 ovarian cancer patients undergoing primary debulking surgery (0%, 63.1)	At least 6 months	L3	SMI (CT) MD (CT)	OS	• SMI <38.73 cm^2/m^2 is the best cut-point for predicting OS • Low SMI (sarcopenia): o Univariate: HR 1.54* o Multivariate: HR 1.36 • Low MD: o Univariate: HR 1.42*
Sabel, 2011, USA[84]	P	101 stage III melanoma patients (62%, 52.8)	21 months	L4 psoas	MD (CT)	PFS	• Low MD: o Univariate: HR 1.82**
Sánchez-Torralvo, 2021, Spain[85]	P	208 patients with active cancer (55%, 60.5)	Not stated	L3	CSA (CT) SMI (CT) MD (CT)	OS	• In survivors vs. deceased after 6 months: o Higher CSA: 126 vs. 113 cm^2** o Higher MD: 41 vs. 32 HU** o Higher SMI: 45.7 vs. 41.3 cm^2/m^2** • Higher 6-month mortality in GLIM-malnourished using SMI: o Multivariate: HR 2.47*
Shachar, 2017, USA[86]	P	40 metastatic breast cancer patients receiving Taxane-based chemotherapy (55)	1.9 years	L3	SMI (CT) MD (CT) SMG (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 2.21 • Low MD: o Univariate: HR 1.02 • Low SMG: o Univariate: HR 1.07
Shaver, 2022, USA[87]	R	403 head and neck cancer patients (82%, 60.9)	64.5 months	L3	SMI (CT) MD (CT)	OS	• Low SMI after propensity-score matching for 5-year OS: o 52.9 vs. 67.3% o Univariate: HR 1.58* • Low MD: o 55.8 vs. 63.4% 5-year survival o Univariate: HR 1.55*
Sheikhbahaei, 2020, USA[88]	R	22 prostate cancer patients (100%, 58)	34.5 months	Psoas at L3-4	CSA (CT) MD (CT)	PFS	• No correlation between survival and CSA or MD
Sjoblom, 2016, Norway[89]	R	734 NSCLC patients (57.2%, 65.4)	Not stated	L3 (all muscles)	SMI (CT) MD (CT)	OS	• Low SMI in men: o Univariate: HR 1.02* o Multivariate: HR 1.02 (gender, age, disease stage, PS1, PS2, BMI, loss of appetite)
Song, 2018, South Korea[90]	R	1460 breast cancer patients (0%, 46)	8.07 years	L3 (all muscles)	Muscle volume (CT)	OS	• Lower volume: o Worse 5-year OS: 94.9% vs. 98%** o Univariate: HR 1.78*

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
						PFS	• Lower volume: o Worse 5-year OS: 89.6% vs. 94.6%* o Univariate: HR 1.39*
Sütcüoğlu, 2023, Turkey[91]	R	74 glioblastoma multiforme patients (62%, 57)	Not stated	Temporal muscle at level of orbital roof	MT (MRI) CSA (MRI)	OS	• Low MT: o Univariate: HR 1.37 • Low CSA: o Univariate: HR 1.69
Souwer, 2019, the Netherlands[92]	P	174 (70 years or older) colorectal cancer patients (51%, 78)	956 days	Psoas, paraspinal, TA, EO, IO, RA at L3	SMI (CT) MD (CT)	OS	• Low SMI (1-year OS): o Univariate: HR 1.08 o Multivariate: HR 1.05 • Low MD (1-year OS) o Univariate: HR 1.49 o Multivariate: HR 1.43
Souza, 2019, Brazil[93]	P	188 colorectal cancer patients (57%, 61)	17 months	L3	SMI (CT) SMI (BIA)	OS	• Severe muscle loss by lower SMI on CT: o Multivariate: HR 2.14* (age, gender, and prior cancer treatment) • Severe muscle loss by lower SMI on BIA: o Multivariate: HR 2.46* (age, gender, and prior cancer treatment) • Moderate muscle loss: NS
Suzuki, 2016, Japan[94]	R	90 stage 1 NSCLC patients undergoing complete resection (57.8%, 68.7)	Not stated	L3	SMI (CT)	OS	• Low SMI (sarcopenia): o Lower 5-year survival: 72.8 vs.85.8%* o Univariate: HR 2.71* o Multivariate: HR 7.09** (gender, stage, differentiation)
Taguchi, 2015, Japan[95]	R	64 metastatic urothelial carcinoma patients (80%, 68)	Not stated	L3 Psoas at umbilicus Psoas at L3	SMI (CT) TPA (CT) MT psoas (CT)	CSS	• Low SMI: o Multivariate: HR 2.07* • Other predictors of CSS: o Psoas CSA* o Umbilical psoas MT*
Takeoka, 2016, Japan[96]	R	56 newly diagnosed multiple myeloma patients (34%, 71)	2.3 years	L3 (Psoas, abdominal RA, paraspinal)	SMI (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 1.96 o Multivariate: HR 2.32
Thormann, 2021, Germany[97]	R	60 breast cancer patients (0%, 57)	Not stated	Psoas at L3	MD (CT) CSA (CT) PMI (CT) SMG (CT)	OS	• Low MD: o Univariate: HR 1.03 • Low CSA: o Univariate: HR 0.96 • Low PMI: o Univariate: HR 0.95 • Low SGM: o Univariate: HR 1.00
Troschel, 2019, Germany[98]	R	128 lung cancer patients undergoing pneumectomy (55.5%, 61)	23.6 months	T8	CSA (CT)	OS	• CSA per 10 cm^2 decrease: o Multivariate: HR 1.25*
Troschel, 2021, Germany[99]	R	367 patients undergoing pneumonectomy for lung cancer (stage IIIA NSCLC (45.5%) and squamous cell histology (58%)) (67%, 62.2)	20.5 months	T8, T10, T12 (all muscles)	CSA (CT)	OS	• Low CSA <2SD (sarcopenia): o Lower OS: 17.7 vs. 46.5 months** o Multivariate: HR 1.68**
						CSS	• Low CSA <2SD (sarcopenia): o Lower CSS: 29.4 vs. 78.9 months** o Multivariate: HR 1.74**
Ueki, 2022, Japan[100]	R	96 patients with renal cell carcinoma who received Nivolumab (74%, >75y)	9.7 months	L3 (all muscles)	SMI (CT) PMI (CT)	OS	• Low SMI (sarcopenia): o Univariate: HR 1.15 • Low PMI (sarcopenia): o Shorter OS: 10.1 vs. 48.4 months** o Univariate: HR 4.53** o Multivariate: HR 3.85**

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
						PFS	• Low SMI (sarcopenia): o Univariate: HR 1.07 • Low PMI (sarcopenia): o Univariate: HR 2.45* o Multivariate: HR 1.80*
Van Baar, 2018, the Netherlands[101]	R	1681 early stage colorectal cancer patients (59%, 67.7)	48 months	Ps, ES, QL, TA, EO, IO, RA	MD (CT)	OS	• Low MD: o Univariate HR 1.91* • Low MD (COLON-study): o Univariate HR 2.15* • MD (continuous): HR 0.98*
						PFS	• Low MD: o Univariate: HR 1.68*
Van der Zanden, 2021, the Netherlands[102]	R	213 women ≥ 70 years old receiving surgery for primary, advanced stage ovarian cancer (0%, 75.9)	Not stated	L3	MD (CT) SMI (CT)	OS	• No association MD or SMI with 30 days, 6 months, or 1-year mortality
Van Rijssen, 2017, the Netherlands[103]	P	166 patients undergoing pancreatoduodenectomy for periampullary non-pancreas cancer (62.6%, 63)	71 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.33 • Low MD: o Univariate: HR 2.44** o Multivariate: HR 1.95* (age, women, ASA, tumor category, lymph node metastasis, tumor differentiation)
Van Vugt, 2018, the Netherlands[104]	P	816 stage I-III colorectal cancer patients (54%, 70)	76.5 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.35* o Multivariate: HR 1.06 • Low MD: o Univariate: HR 1.75** o Multivariate: HR 0.91
						PFS	• No difference in low vs. high SMI or MD
Van Vugt, 2019, the Netherlands[105]	R	233 perihilar cholangiocarcinoma patients (60.1%, 66)	25.3 months	L3	SMI (CT) MD (CT)	OS	• Low SMI: o Univariate: HR 1.99 • Low MD: o Univariate: HR 3.38** for 3-month survival; HR 1.92* after 1 year. o Multivariate: HR 1.78* after 6 months (age, tumor size and suspected metastases)
Von Geldern, Chili, 2020[106]	P	103 adult cancer patients (45%, 54.9)	38 months	Psoas at L3	SMI (CT)	OS	• Low SMI (sarcopenia): o Multivariate: HR 2.38*
Williams, 2021, USA[107]	R	142 multiple myeloma patients undergoing autologous stem cell transplantation (65%, 61.6)	27-33 months	Psoas at L3	MD (CT)	OS	• Sarcopenia as defined by 80% high density muscle: o Multivariate: HR 1.28
Xiao, 2022, China[108]	R	172 patients with primary liver cancer (87%, 51.4)	9 months	L3 (all muscles)	SMI (CT) MD (CT)	OS	• Low SMI (sarcopenia): o Univariate HR 4.90 ** o Multivariate: HR 5.39** (gender, BMI, ECOG PS score, Child–Pugh score, baseline metastasis, CRP, and NLR) • Low MD: o Univariate: HR 1.64 o Multivariate: HR 1.06
						PFS	• Low SMI (sarcopenia): o Univariate: HR 1.62 ** • Low MD: o Univariate: HR 0.83 o Multivariate: HR 0.56* (gender, BMI, ECOG PS score, Child–Pugh score, baseline metastasis, CRP, and NLR)

Table 4. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (year))	Mean follow-up	Investigated muscle(s)	Muscle parameters + imaging method	Outcome	Statistical results
Yamashita, 2020, Japan[109]	R	230 bladder cancer patients undergoing radical cystectomy (80%, 73)	25.5 months	Psoas at L3	MD (CT)	OS	• Low MD: o Univariate: HR 1.04* o Multivariate: HR 1.02
						CSS	• Low MD: o Univariate: HR 1.04** o Multivariate: HR 1.07 • Low MD: o Univariate: HR 1.04** o Multivariate: HR 1.04* (ECOG PS≥1, low ATPD, non-UC, pT≥3, and pN positivity)
Yan, 2021, China[110]	R	261 glioma patients (53%, 47)	Not stated	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Low MT < 7.5 mm: o Univariate: HR 4.61** o Multivariate: HR 3.50** o Survival: 11 vs. 22 months* o 1-, 2- and 3-year survival in thinner vs. thicker groups: 46.5%, 28.8%, 13.6% vs. 93.6%, 78.4%, 58.3% *
Yesil, 2020, Turkey[111]	R	47 glioblastoma multiforme patients (62%, 56)	Not stated	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Low MT < 4.9: o Univariate: HR 2.40* o Multivariate: HR 2.07* (age)
Yesil, 2020, Turkey[112]	R	94 lung cancer patients with brain metastasis (SCLC and NSCLC) (87%, 60)	Not stated	Temporal muscle at level of orbital roof	MT (MRI)	OS	• Low MT <4.32: o Univariate: HR 1.23* o Per 1 mm reduction of MT: increased risk of death of 18.8%*
Yokoi, 2022, Japan[113]	R	341 stage III colorectal cancer patients (59%, 70)	44 months	L3	SMI (CT) MD (CT)	PFS	• Lower SMI (men): o Univariate: HR 2.38** o Multivariate: HR 1.87** o Lower MD (men): o Univariate: HR 2.37** o Multivariate: 1.47
Youn, 2021, Canada[163]	R	44 metastatic myeloma patients treated with Nivolumab (57%, 57)	Not stated	L3	MD (CT)	OS	• Low MD < 25.65 HU: o Univariate: HR 3.81** o Multivariate: HR 4.40** (age, gender, performance status, and number of prior lines of therapy)
Young, 2020, USA[164]	R	287 melanoma patients treated with immune checkpoint inhibitors (64%, 63)	519 days	L3	SMI (CT) MD (CT) SMG (CT)	OS	• Low SMI: o Univariate: HR 1.15 • Low MD: o Univariate: HR 1.03 • Low SMG: o Univariate: HR 1.11
						PFS	• Low SMI: o Univariate: HR 1.28 • Low MD: o Univariate: HR 1.32 • Low SMG: o Univariate: HR 1.28

** = P<0.05; ** = P<0.01. ADC = adeno-type cell carcinoma; Allo-HCT = allogeneic hematopoietic cell transplantation; ASA = American Society of Anesthesiologists; ATPD = average total psoas muscle density; auto-HCT = autologous hematopoietic cell transplantation; BCLC = Barcelona Clinic Liver Cancer; BIA = bioelectrical impedance analysis; BMI = body mass index; BRAF = v-Raf murine sarcoma viral oncogene homolog B; C3 = cervical vertebra 3; CCI = Charlson comorbidity index; CNS = central nervous system; CRP = C-reactive protein; CSA = cross-sectional area; CSS = cancer-specific survival; CT = computed tomography; DM = diabetes mellitus; DXA = dual-energy X-ray absorptiometry; ECM = extracranial metastasis; ECOG = Eastern Cooperative Oncology Group, ECOG-PS = Eastern Cooperative Oncology Group performance status; EO = external oblique; ES = erector spinae; 5-FU = 5-fluorouracil; FLIPI = Follicular Lymphoma International Prognostic Index; GLIM = Global Leadership Initiative on Malnutrition; HCC = hepatocellular carcinoma; HR = hazard ratio; HU = Hounsfield units; IO = internal oblique; IPI = International Prognostic Index; IT = immunotherapy; KPS = Karnofsky Performance Status; L3 = lumbar vertebra 3; L4 = lumbar vertebra 4; LD = latissimus dorsi; LDH = lactate dehydrogenasis; MD = muscle density; mFI = modified frailty index; MMC = mitomycin C; MRI = magnetic resonance imaging; MT = muscle thickness; MTX = methotrexate; NLR = neutrophil-to-lymphocyte ratio; non-UC = non-urothelial carcinoma; NS = not significant; NSCLC = non small cell lung cancer; OR = odds ratio; OS = overall survival, P = prospective; PD-1 = Programmed Cell Death Protein 1; PD-L1 = Programmed Cell Death Ligand 1; PFS = progression-free survival; Pm = psoas minor; PM = psoas major; PMA = psoas muscle area; PMI = psoas muscle index; Ps = paraspinal; PS = performance status; PT = proximal thigh; PVMI = paravertebral muscle index; RPA = recursive partitioning analysis, QF = quadriceps femoris; QL = quadratus lumborum; R = retrospective; RA = rectus abdominus; RF = rectus femoris; R-IPI = revised International Prognostic Index; SC = subcutaneous; SCC = squamous cell carcinoma; SCM = sternocleidomastoid muscle; SMLC = small cell lung cancer; SMG = skeletal muscle gauge; SMI = skeletal muscle index (=CSA/height2); T4 = thoracic vertebra 4; T8 = thoracic vertebra 8; T10 = thoracic vertebra 10; T12 = thoracic vertebra 12; TA = transverse abdominis; TACE = Transarterial chemoembolization; TMT = temporal muscle thickness; TNM = tumor, nodes and metastasis classification; TT = targeted therapy; US = ultrasound; vs. = versus*

Table 5. Characteristics and results of included studies on chemotoxicity.

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Aleixo, 2021, USA[165]	R	338 stage I-III breast cancer patients receiving (neo)adjuvant chemotherapy (51)	Not stated	L3 (all muscles) Psoas ES	MD (CT)	For L3 MD: • RR for any AE (cont): 0.74** For myosteatosis: 1.81 • RR for dose reduction (cont): 0.78* For myosteatosis: 1.54 • RR for treatment discontinuation (cont): 0.66** For myosteatosis: 2.44 • RR for hospitalisation due to AE (cont): 0.73** For myosteatosis: 1.69 For psoas MD: • RR for any AE (cont): 0.73** For myosteatosis: 1.8 • RR for dose reduction (cont): 0.77* For myosteatosis: 1.8 • RR for treatment discontinuation (cont): 0.68** For myosteatosis: 2.82 • RR for hospitalization due to AE (cont): 0.75* For myosteatosis: 1.58 For ES MD: • RR for any AE (cont): 0.81** For myosteatosis: 1.66 • RR for dose reduction (cont): 0.82** For myosteatosis: 1.72 • RR for treatment discontinuation (cont): 0.72** • For myosteatosis: 2.61
Al Khaldi, 2022, Canada[25]	R	312 patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy for peritoneal metastases (34.3%, 57.6)	28 months	L3 (all muscles)	SMI (CT)	• SMI-based sarcopenia did not have a significant effect on HIPEC toxicity
Bardoscia, 2022, Italy[30]	R	225 head and neck cancer patients undergoing (chemo)radiation (75.6%, 64.5)	5.6 year	L3 (all muscles)	SMI (CT) MD (CT)	• Both low SMI and low MD did not significantly alter rates of chemotherapy suspension or acute toxicity
Chu, 2020, Canada[38]	R	97 metastatic melanoma patients treated with Ipilimumab (60%, 56)	Not stated	L3 (all muscles)	MD (CT)	• High MD causes more immune-related adverse events (21.7 vs. 11.3%, P0.051) • High MD is related to lower NLR values (21 vs. 39%*)
Cortellini, 2020, Italy[161]	R	100 patients with advanced cancer receiving anti-PD-1/PD-L1 checkpoint inhibitors (67%, 66)	20.3 months	L3 (all muscles)	SMI (CT) MD (CT)	• No significant difference in irAEs in low vs. non-low SMI (P0.49) • No significant difference in irAEs in low vs. non-low MD (P0.21)

Table 5. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Cushen, 2014, Ireland[41]	R	55 metastatic renal cell carcinoma patients treated with Sunitinib (78%, 66)	6 months	L3 (all muscles)	CSA (CT) SMM (CT)	• Lower CSA (151.5 vs. 173.7cm^2) causes earlier DLT < 6 months** • Lower SMI (51.7 vs. 59.4 cm^2/m^2) causes earlier DLT < 6 months * • In < 25th SMM centile (44.8 cm^2/m^2) compared to >75th centile (63.2 cm^2/m^2): o More DLT (92% vs. 57%*) o More early DLT <6 months (77 vs. 28%*) o Higher number of toxicities (2.7 vs.1.8%**)
Dijksterhuis, 2019, the Netherlands[43]	R	88 advanced esophagogastric cancer patients treated with 1st line CapOx (75%, 63)	Not stated	L3 (all muscles)	SMI (CT) MD (CT)	• Lower pre-treatment MD is associated with more CTCAE grade 3/4: OR 0.94* • SMI-based sarcopenic obesity is associated with peripheral sensory neuropathy CTCAE ≥2: OR 3.82*
Ganju, 2019, USA[162]	R	46 stage IB-IVA endometrial cancer patients treated with hysterectomy and pelvic radiation (0%, 61)	27 months	L3 (all muscles)	SMI (CT) MD (CT)	• Neither SMI alone (P = 0.51), MD alone (P = 0.10) nor both adverse features (P = 0.07) were correlated with delays during radiation due to toxicity • Neither low SMI (P = 0.08) nor low MD (P = 0.25) were associated with inability to complete or delays in chemotherapy • Patients with both low SMI and low MD were less likely to complete chemotherapy: 94% vs. 58%** • Predictors of failure of chemotherapy completion: o Low SMI: OR 4.47 (P0.08) o Low MD: OR 0.16 (P0.25) • Low SMI + low MD: OR 9.55**
Haehl, 2022, Germany[48]	R	280 head and neck squamous cell carcinoma patients receiving curative (chemo) radiation (gender not stated, age >65)	127 days	C3 (paravertebral + SCM) L3 (calculated from C3)	CSA (CT) SMI (CT)	• Acute toxicity related to CSA: ρ -0.111 (P0.06) • Acute toxicity related to SMI: ρ -0.147* • Chronic toxicity not related to CSA or SMI • Higher acute toxicity in SMI-defined sarcopenia: 20.8, 69.4 and 9.7% for maximum CTCAE grade 2, 3 and 4 toxicities, compared to 30.9, 66.2 and 3.0%* • Higher chronic grade III/IV toxicity in low L3 CSA: 24.8 vs. 11.8%* • No significant effect of SMI on chronic toxicity
Huang, 2020, China[117]	P	82 nasopharyngeal carcinoma patients treated with (chemo) radiotherapy (67%, 45.7)	Until the end of the RT	L3 (all muscles)	CSA (CT) SMI (CT) MD (CT)	• Predictors of CTCAE grade 3-4 chemotoxicity: o CSA: OR 0.98* o SMI: OR 0.95 (P0.06, women) o MD: NS o Sarcopenia (defined by SMI): NS • Higher DLT in sarcopenic men: OR 4.00* • Higher DLT in lower CSA: OR 0.97* • Higher DLT in lower SMI: OR 0.91* • No correlation between severe RT toxicity and muscle loss
Kim, 2021, South Korea[55]	R	330 pancreatic cancer patients undergoing chemotherapy (49%, 63.4)	Not stated	L3 (all muscles)	MD (CT) SMI (CT)	• Higher grade ≥3 toxicity in low SMI: 59 vs. 43%* • Higher grade ≥3 toxicity in low MD: 60 vs. 44%* • No differences in neutropenia, anaemia, thrombocytopenia, fatigue or diarrhea in high or low SMI or MD
Looijaard, 2019, the Netherlands[63]	R	378 colorectal cancer patients (60.3, 73.4)	5.3 years	L3 (all muscles)	MD (CT) SMI (CT)	• SMI and MD could not predict DLT

Table 5. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Martin, 2020, Germany[65]	R	114 anal carcinoma patients treated with 5-FU or MMC (51%, 58.5)	30 months	L4 (all muscles)	SMI (CT)	• Patients with SMI-determined sarcopenia suffer more leukopenia: 56 vs. 27%** • Sarcopenia gives higher rates of thrombocytopenia: 22 vs. 6%* • No difference regarding diarrhea or dermatitis
Mazzuca, 2018, Italy[118]	R	21 stage I-III breast cancer patients undergoing anthracycline-based adjuvant therapy (0%, 54)	Not stated	L3 (all muscles)	CSA (CT) SMI (CT)	• Lower SMI in G3-4 toxicity: 40.5 vs. 33.4 cm^2/m^2* • Lower CSA in G3-4 toxicity: 109 vs. 86.8 cm^2 * • L3 SMI = independent predictor of G3-4 toxicity in multivariate analysis*
Miyamoto, 2018, Japan[70]	R	52 metastatic colorectal cancer patients (62%, 67)	4 months	L3 (all muscles)	SMI (CT)	• Low SMI (<50.9 (M) or <39.1 (F)) cm^2/m^2: more CTCEA grade 3-4 adverse events than high SMI group (>52.8 (M) or >39.2 (F): 46 vs. 12%*
Phuong, 2022, USA[119]	R	141 testicular germ cell carcinoma patients (100%, 30)	Not stated	L3 (all muscles)	SMI (CT) MD (CT) SMG (CT)	• Higher incidence of adverse events if: o Post-chemo decrease in SMI: OR 0.89* o Post-chemo decrease in SMG: OR 0.88* o Post-chemo decrease in SMG: OR 0.94* • Pre-chemotherapy muscle status and post-chemotherapy SMI and MD were not associated with adverse events.
Shachar, 2017, USA[86]	P	40 metastatic breast cancer patients receiving taxane-based chemotherapy (100%, 55)	1.9 years	L3 (all muscles)	SMI (CT) SMG (CT)	• Higher toxicity in sarcopenia patients (SMI < 41 cm^2/m^2): 57% vs. 18%* • Higher toxicity-related hospitalizations in sarcopenia: 39 vs. 0%** • Higher rate of adverse events of any kind (hospitalization, grade 3–4 toxicity, dose reductions, dose delay) in sarcopenic patients: 74 vs. 35%* • Low SMG: more toxicity*, more hospitalizations*, more adverse events (P0.06)
Smit, 2022, the Netherlands[120]	R	202 colorectal cancer survivors (54%, 66)	Not stated	L3 (all muscles)	SMI (CT) MD (CT)	• No significant associations were found between MD or SMI and total chemotherapy-induced peripheral neuropathy. • No significant associations were found for MD or SMI with motor, sensory, or autonomic chemotherapy-induced peripheral neuropathy.
Youn, 2021, Canada[163]	R	44 metastatic myeloma patients treated with Nivolumab (57%, 57)	Not stated	L3 (all muscles)	MD (CT)	• MD did not alter toxicity (gastro-intestinal, transaminitis, dermatitis, endocrinopathy)
Young, 2020, USA[164]	R	287 melanoma patients treated with immune checkpoint inhibitors (64%, 63)	519 days	L3 (all muscles)	MD (CT) SMI (CT) SMG (CT)	• SMI, MD and SMG did not have a significant effect on chemotoxicity

** = P<0.05; ** = P<0.01. AE = adverse events; C3 = cervical vertebra 3; CSA = cross-sectional area; cont. = continuous; CT = computed tomography; CTCAE = Common Terminology Criteria for Adverse Events; DLT = dose-limiting toxicity; ES = erector spinae; 5-FU = 5-fluorouracil; HIPEC = hyperthermic intraperitoneal chemotherapy; ir-AE = Immune-Related Adverse Events; L3 = lumbar vertebra 3; MD = muscle density; MMC = mitomycin C; NLR = neutrophil-to-lymphocyte ratio; NS = not significant; OR = odds ratio; P = prospective; PD-1 = Programmed Cell Death Protein 1; PD-L1 = Programmed Cell Death Ligand 1; R = retrospective; RR = relative risk; RT = radiotherapy; SCM = sternocleidomastoid muscle; SMG = skeletal muscle gauge; SMI = skeletal muscle index; vs. = versus*

Table 6. Characteristics and results of included studies on surgical outcomes in oncology patients.

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Al Khaldi, 2022, Canada[25]	R	312 patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy for peritoneal metastases (34.3%, 57.6)	28 months	L3 (all muscles)	SMI (CT)	• No effect of SMI-defined sarcopenia on CD ≥ 3 complications
Arayne, 2023, Australia[27]	R	80 stage I – III rectal cancer patients undergoing curative resection (74%, 63)	Not stated	T4, T12, L3 (all muscles)	SMI (CT)	• No effect of SMI on medical or surgical complications.
Asai, 2023, Japan[29]	R	456 patients undergoing major hepatectomy for perihilar cholangiocarcinoma (68%, 69)	Not stated	Psoas at L3	MD (CT) TPI (CT)	• Lowest tertile of TPI: o No difference on operation time, CD > 3, bile leakage, liver failure, infectious complications, wound infections, abscesses o Higher intra-operative blood loss: 21.3 ml/kg vs. 17.2 ml/kg** o More bacteriaemia: 8 vs. 3%* o More ascites: 16 vs. 7%** • Lowest tertile of MD: o No difference in operation time, intra-operative blood loss, bile leakage, liver failure, wound infections, bacteriaemia, ascites o More CD > 3 complications: 55 vs. 44%* o More infectious complications: 41 vs. 26%** o More abscesses: 33 vs. 22%*
Baker, 2018, USA[121]	P	298 patients undergoing abdominal surgery for cancer treatment (46%, 60)	Not stated	Psoas at L3	MD (CT) CSA (CT)	• Patients who had complications had lower MD: 22.4 vs. 24.4 HU* • MD: OR 0.937* • No difference in total psoas area in complications vs. non-complication group
Bozkurt, 2018, Turkey[122]	R	60 advanced laryngeal cancer patients (100%, 59.4)	Not stated	Paravertebral muscles at C3	PvMI (CT)	• Patients who had complications had a lower neck muscle index: 770 vs. 875 mm^2/m^2*
Chakedis, 2018, USA[34]	R	177 biliary tract cancer patients (44%, 66)	12.2 months	L3 (all muscles) Psoas	PMI (CT)	• PMI-defined sarcopenia did not have a significant effect on postoperative complication rates
Cinar, 2022, Turkey[39]	R	180 patients undergoing resection for NSCLC (80%, 65)	26.3 months	T12 para-vertebral muscles	PvMI (CT) MD (CT)	• More complications in low PvMI: 18 vs. 3.3%* • More complications in low MD: 19 vs. 4.3%**
Fintelmann, 2018, USA[123]	R	135 patients who underwent lobectomy or bilobectomy for primary lung cancer (42%, 69)	Not stated	T5 (all muscles)	CSA (CT)	• Higher risk of any postoperative complications with lower CSA: OR 0.86* • Higher risk of postoperative respiratory complications with lower CSA: OR 0.80* • Higher risk of postoperative ICU admission with lower CSA: OR 0.73*
Galli, 2022, Italy[124]	R	65 stage III-IV head and neck cancer patients (82%, 65.9)	Not stated	RF C3 (paravertebral and SCM)	CSA (US) CSA (CT/MRI) SMI (CT/MRI)	• Higher 30-days major complications: o RF CSA <1.32cm^2: OR 7.72** o C3 CSA <34.91 cm^2: OR 4.11** o CT SMI <11.25 cm^2/m^2: OR 2.9*
Hirai, 2020, Japan[49]	R	163 soft tissue sarcoma patients (59.5%, 64.2)	27 months	L3 (all muscles)	CSA (CT) MD (CT) SMI (CT) SMG (CT)	• CSA, and SMI were not risk factors for wound complications • More wound complications in low MD: 18 vs. 3%** • More wound complications in low SMG: 17 vs. 4%**; OR 3.27**

Table 6. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Huang, 2021, China[51]	P	587 patients (with BMI >23 kg/m2) who underwent radical gastrectomy for the treatment of gastric cancer (74%, 65)	43.8 months	L3 (all muscles)	MD (CT)	• Higher postoperative complications in GLIM-defined malnutrition + low MD-based muscle quality: 38.1 vs. 28.6% in GLIM alone*; OR 2.03* (GLIM alone: NS)
Huang, 2021, China[50]	P	597 patients (gender not stated, aged 65+ years) who underwent radical gastrectomy for gastric cancer (77%, 72)	33.5 months	L3 (all muscles)	SMI (CT) MD (CT)	• Low SMI had higher postoperative complications: OR 1.54* • Low MD: no effect on complication risk
Joglekar, 2015, USA[125]	R	118 patients who underwent pancreatico-duodenectomy or distal pancreatectomy (64%)	Not stated	Psoas at L3	PMI (CT) MD (CT)	• Risk of ICU admission per 5 units HUAC decrease: OR 2.33* • Risk of any complication per 5 units HUAC decrease: OR 2.78* • Risk of major grade III complications per 5 units HUAC decrease: OR 3.45* • Risk of infectious complications per 5 units HUAC decrease: OR 1.69* • Risk of gastro-intestinal complications per 5 units HUAC decrease: OR 1.75* • Risk of pulmonary complications per 5 units HUAC decrease: OR 2.56* • Risk of cardiac complications per 5 units HUAC decrease: OR 2.70* • Risk of delayed gastric emptying per 5 units HUAC decrease: OR 2.33*
Kim, 2019, South Korea[126]	P	50 colorectal cancer patients (56%, 63.4)	Not stated	Back muscles at L3	SMM (BIA)	• SMM had no effect on postoperative ileus or surgical site infection
Kim, 2018, South Korea[127]	R	272 newly diagnosed, pathologically proven NSCLC patients that underwent curative-intent surgery (60%, 62.9)	Not stated	L3 (all muscles)	SMI (CT)	• SMI-defined sarcopenia did not affect postoperative complications
Kuroki, 2015, USA[57]	R	122 endometrial cancer patients (0%, 65.9)	Not stated	Psoas L3	CSA (CT)	• CSA-based sarcopenia was not associated with postoperative complications
Lanza, 2020, Italy[58]	R	142 HCC patients who received bland transarterial embolization (77%, 73)	27 months	L3 (all muscles)	SMI (CT)	• No significant difference between sarcopenic and non-sarcopenic patients concerning early complication rates
Looijaard, 2019, the Netherlands [63]	R	378 colorectal cancer patients (60.3, 73.4)	5.3 years	L3 (all muscles)	MD (CT) SMI (CT)	• No significant correlation between MD or SMI and severe surgery-related complications
Lin, 2019, China[128]	R	594 patients undergoing radical surgery for primary gastric cancer treatment (75%, 64.3)	Not stated	L3 (all muscles)	MD (CT) SMG (CT) SMI (CT)	• Factors associated with postoperative complications: o MD (low/high): HR 1.61* o SMI (low/high): 1.91** o SMG (low/high): 2.45**

Table 6. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Martini, 2020, France[129]	R	234 lung cancer patients undergoing pneumonectomy (71%, 64)	Not stated	L3 (all muscles)	CSA (CT) SMI (CT)	• CSA-based sarcopenia: o Increased ARDS risk: 58.3 vs. 31.9%* o Increased risk of acute respiratory failure: 52.5 vs. 30.9%** • SMI-based sarcopenia: o Increased ARDS risk: 58.3 vs. 31%** o Increased risk of acute respiratory failure: 50 vs. 30.4%*
Namm, 2017, USA[130]	P	116 undergoing pancreatico-duodenectomy for pancreatic malignancy (53%, 65.5)	33 months	Psoas at L3	MD (CT) PMI (CT)	• No effect of TPI or MD on major complications, wound infection, return to ICU • Higher risk of organ infection/pancreas fistula with low TPA: OR 2.41* (MD NS).
Nishigori, 2016, Japan[131]	R	199 thoracic esophageal cancer patients who underwent esophagectomy (82%, 65)	Not stated	L3 (all muscles	SMI (CT)	• No difference in complication rates between SMI-defined sarcopenia and non-sarcopenia • Sarcopenia group: more pulmonary complications: 32 vs. 12%**; OR 3.38* • No difference concerning cardiac, gastro-intestinal, infectious, neurologic, thrombo-embolic, or other complications
Rutten, 2017, the Netherlands [83]	R	216 ovarian cancer patients undergoing primary debulking surgery (0%, 63.1)	At least 6 months	L3 (all muscles)	SMI (CT) PMI (CT) MD (CT)	• Low MD associated to a higher risk of major complications: OR 2.32* • No significant risk in SMI-based sarcopenia or PMI
Sabel, 2011, USA [84]	P	101 stage III melanoma patients (62%, 52.8)	21 months	L4 psoas	CSA (CT) MD (CT)	• Risk for complications: o CSA: OR 1.001* o MD per 10 HU: OR 1.08*
Şengül Ayçiçek, 2021, Turkey[132]	P	49 gastrointestinal cancer patients (51%, 70)	Not stated	RA, IO, EO, TA, RF, GM	CSA (US) SMI (BIA)	• Wound infection, non-infectious complications, anastomotic leakage: not correlated to sarcopenia as measured by SMI
Souwer, 2019, the Netherlands [92]	P	174 70y+ colorectal cancer patients (51%, 78)	956 days	Psoas, paraspinal, TA, EO, IO, RA at L3	SMM (CT) MD (CT)	• SMM: o Cardiac complications: OR 0.44* o No difference in pulmonary complications or severe complications • MD: o Higher risk of any complication in Q1 vs. Q4: 49 vs. 28%*; OR 0.78 (P0.08) o More pulmonary complications in Q1 vs. Q4: 14 vs. 2%*, OR 0.53* o More cardiac complications in Q1 vs. Q4: 16 vs. 2%*, OR 0.42* o More severe complications in Q1 vs. Q4: 28 vs. 7%*, OR 0.72 (P0.06)
Sun, 2022, Japan[133]	R	341 NSCLC patients undergoing lobectomy (59%, 70)	65 months	Pectoralis at T4	PeMI (CT) MD (CT)	• More major complications in lower MD: 27.1, 13.8, 15.5 and 8.2%* • More major complications in lower PeMI: 22.4, 18.4, 16.7, and 7.1%*
Suzuki, 2016, Japan[94]	R	90 stage I NSCLC patients undergoing complete resection (57.8%, 68.7)	Not stated	L3 (all muscles)	SMI (CT)	• SMI-based sarcopenia did not have a significant effect on postoperative complications
Van der Zanden, 2021, the Netherlands [102]	R	213 women ≥ 70 years old receiving surgery for primary, advanced stage ovarian cancer (0%, 75.9)	Not stated	L3 (all muscles)	MD (CT) SMI (CT)	• Higher complications in low MD: 53.7 vs. 29.1%**; OR 2.83* • Higher infectious complications in low MD: 34.1 vs. 25.7%*; OR 2.79* • Higher severe complications in low MD: 17.1 vs. 6.4%*; OR 3.01* • No differences in MD in severe delirium • Low SMI and infectious complications: OR 2.32* • No association between SMI and other outcomes

Table 6. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Van Rijssen, 2017, the Netherlands [103]	P	166 patients undergoing pancreatoduodenectomy for periampullary non-pancreas cancer (62.6%, 63)	71 months	L3 (Psoas, ES, QL, EO, IO, RA, TA)	SMI (CT) MD (CT)	• SMI did not show significant effect on overall morbidity, major complications, postoperative fistulas, postpancreatectomy hemorrhages or delayed gastric emptying • Low MD: o Higher overall morbidity: 75.3 vs. 57.6%* o Higher incidence of major complications: 58 vs. 36.5%** o More postpancreatectomy hemorrhages: 11.1 vs. 2.4%* o More delayed gastric emptying: 46.9 vs. 29.4%*
Van Vugt, 2018, the Netherlands [104]	P	816 stage I-III colorectal cancer patients (54%, 70)	76.5 months	L3 (all muscles)	SMI (CT) MD (CT)	• Low SMI: o No effect on overall complications o More CD ≥ 3 complications: 20.9 vs. 13.6** • Low MD: o More overall complications: 51.7 vs. 38.5%** o More CD ≥ 3 complications: 20 vs. 11.8%**
Williams, 2021, USA [107]	R	142 multiple myeloma patients undergoing autologous stem cell transplantation (65%, 61.6)	27-33 months	Psoas at L3	MD (CT)	• Sarcopenia (defined by 80% high density muscle) had a higher rate of cardiovascular complications: 12.5 vs. 2.9%* • No significant effect on other complications

** = P<0.05; ** = P<0.01. ARDS = Acute respiratory distress syndrome; BIA = bioelectrical impedance analysis; BMI = body mass index; C3 = cervical vertebra 3; CD = Clavien-Dindo; CSA = cross-sectional area; CT = computed tomography; EO = external oblique; GLIM = Global Leadership Initiative on Malnutrition; GM = Gastrocnemius medialis; HCC = hepatocellucar carcinoma; HR = hazard ratio; HU = Hounsfield units; HUAC = Hounsfield unit average calculation; ICU = intensive care unit; IO = internal oblique; L3 = lumbar vertebra 3; MD = muscle density; MRI = magnetic resonance imaging; NS = not significant; NSCLC = non small cell lung cancer; OR = odds ratio; P = prospective; PMI = psoas muscle index; PeMI = pectoralis muscle index; PvMI = paravertebral muscle index; QL = quadratus lumborum; R = retrospective; RA = rectus abdominus; RF = rectus femoris; SCM = sternocleidomastoid muscle; SMG = skeletal muscle gauge; SMI = skeletal muscle index; SMM= skeletal muscle mass; T4 = thoracic vertebra 4; T5 = thoracic vertebra 5; T12 = thoracic vertebra 12; TA = transverse abdominis; TPA = total psoas area; TPI = total psoas index; US = ultrasound; vs. = versus*

Table 7. Characteristics and results of included studies on response to treatment in oncology patients.

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Al Khaldi, 2022, Canada [25]	R	312 patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy for peritoneal metastases (34.3%, 57.6)	28 months	L3 (all muscles)	SMI (CT)	• No effect of SMI-defined sarcopenia on completeness of cytoreduction
Arayne, 2023, Australia [27]	R	80 stage I – III rectal cancer patients undergoing curative resection (74%, 63)	Not stated	T4, T12, L3 (all muscles)	SMI (CT)	• No effect of SMI on recurrence
Bardoscia, 2022, Italy [30]	R	225 head and neck cancer patients undergoing (chemo) radiotherapy (75.6%, 64.5)	5.6 years	L3 (all muscles)	SMI (CT) MD (CT)	• No effect of SMI or MD on local disease control
Chiu, 2020, Taiwan [134]	R	183 esophageal cancer patients who received neoadjuvant chemoradiotherapy + esophagectomy (95%, 53)	4 years	Dorsal muscles at L3	CSA (CT) MD (CT)	• Larger CSA was associated with pathological complete response: OR 1.59* • MD: NS
Cho, 2022, Austria [36]	R	566 patients with brain metastases from NSCLC (48%, 63)	Not stated	Temporal muscle at level of orbital roof	MT (MRI)	• No difference on local brain metastasis progression
Haehl, 2022, Germany [48]	R	280 head and neck squamous cell carcinoma patients receiving curative (chemo) radiation (gender not stated, age >65)	127 days	C3 (paravertebral + SCM) L3 (calculated from C3)	CSA (CT) SMI (CT)	• L3 CSA and L3 SMI were no significant predictors of locoregional control

Table 7. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Otemuyiwa, 2017, USA[135]	R	75 metastatic renal cell carcinoma patients initiating IL-2 therapy (67%, 55)	Not stated	Dorsal muscles at T11	MD (CT)	• MD of low-density muscles was a significant predictor of IL-2 response* • OR for responding is 5.8x higher for high-attenuation-low MD muscles* • Optimal cut-off: 18.1 HU*
Shachar, 2017, USA[86]	P	40 metastatic breast cancer patients receiving taxane-based chemotherapy (55)	1.9 years	L3 (all muscles)	SMI (CT) MD (CT) SMG (CT)	• Time to treatment failure is dependent of: o SMI and MD: NS o SMG: OR 0.91*
Kim, 2021, South Korea[55]	R	330 pancreatic cancer patients undergoing chemotherapy (49%, 63.4)	Not stated	L3 (all muscles)	MD (CT) SMI (CT)	• MD and SMI were no significant predictors of treatment response.
Nishioka, 2020, Japan[74]	R	156 NSCLC patients receiving immunotherapy (65%, 67)	Not stated	L3 (all muscles)	MD (CT) SMI (CT)	• Predictors for efficacy of PD-1/PD-L1 inhibitors: o Quality (high MD): HR 0.64* o Quantity (high SMI): NS • Overall response rate higher in high quality: 35 vs. 15.8%*. • No effect of quantity
Pan, 2021, China[136]	R	273 urinary tract urothelial carcinoma patients treated by radical nephroureterectomy (54.2%, 68)	Not stated	L3 (RA, EO, IO, TA, PS, Ps)	MD (CT) SMI (CT) MT (CT)	• Effect on local progression: o MD: NS (multivariate: HR 0.97*) o SMI: NS (multivariate: HR 0.89*)
Young, 2020, USA[164]	R	287 melanoma patients treated with immune-checkpoint inhibitors (64%, 63)	519 days	L3 (all muscles)	MD (CT) SMI (CT) SMG (CT)	• No significant effect of MD, SMI, or SMG on response to treatment

** = P<0.05; ** = P<0.01. C3 = cervical vertebra 3; CSA = cross-sectional area; CT = computed tomography; EO = external oblique; HR = hazard ratio; HU = Hounsfield units; IL-2 = interleukin 2; IO = internal oblique; L3 = lumbar vertebra 3; MD = muscle density; MRI = magnetic resonance imaging; MT = muscle thickness; NS = not significant; NSCLC = non small cell lung cancer; OR = odds ratio; OS = overall survival; PD-1 = Programmed Cell Death Protein 1; PD-L1 = Programmed Cell Death Ligand 1; P = prospective; Ps = paraspinal; PS = psoas muscles; R = retrospective; RA = rectus abdominis; SCM = sternocleidomastoid muscle; SMG = skeletal muscle gauge; SMI = skeletal muscle index; T4 = thoracic vertebra 4; T11 = thoracic vertebra 11; T12 = thoracic vertebra 12; TA = transverse abdominis; vs. = versus*

Table 8. Characteristics and results of included studies on duration of hospitalization and rehospitalization in oncology patients.

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Al Khaldi, 2022, Canada[25]	R	312 patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy for peritoneal metastases (34.3%, 57.6)	28 months	L3 (all muscles)	SMI (CT)	• SMI-defined sarcopenia did not have a significant effect on LOS or duration of TPN.
Arayne, 2023, Australia[27]	R	80 stage I – III rectal cancer patients undergoing curative resection (74%, 63)	Not stated	T4, T12, L3 (all muscles)	SMI (CT)	• SMI-defined sarcopenia did not have a significant effect on LOS
Asai, 2023, Japan[29]	R	456 patients undergoing major hepatectomy for perihilar cholangiocarcinoma (68%, 69)	Not stated	Psoas at L3	MD (CT) TPI (CT)	• Lowest tertile of TPI had longer hospital stay: 26 vs. 24 days* • Lowest tertile of MD had longer hospital stay: 28 vs. 23 days**
Cinar, 2022, Turkey[39]	R	180 patients undergoing resection for NSCLC (80%, 65)	26.3 months	T12 para-vertebral muscles	PvMI (CT) MD (CT)	• Longer LOS in low PvMI: 8 vs. 6 days** • Longer LOS in low MD: 7 vs. 6 days*
Fintelmann, 2018, USA[123]	R	135 patients who underwent lobectomy or bilobectomy for primary lung cancer (42%, 69)	Not stated	T5 (all muscles)	CSA (CT)	• Hospital LOS (in quartiles) was associated with CSA: OR 0.87* • Readmission within 30 days was associated with CSA: OR 0.58*

Table 8. *(Cont. from previous page).*

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Joglekar, 2015, USA[125]	R	118 patients who underwent pancreatico-duodenectomy or distal pancreatectomy (64%)	Not stated	Psoas at L3	TPI (CT) MD (CT)	• LOS was associated with: o MD: OR 2.00* o TPI: OR 1.75*
Kim, 2019, South Korea[126]	P	50 colorectal cancer patients (56%, 63.4)	Not stated	Back muscles at L3	SMM (BIA)	• Longer LOS in low muscle mass group: 11.5 vs. 8.3 vs.6.5 days**
Kim, 2018, South Korea[127]	R	272 newly diagnosed, pathologically proven NSCLC patients that underwent curative-intent surgery (60%, 62.9)	Not stated	L3 (all muscles)	SMI (CT)	• SMI-defined sarcopenia did not affect LOS
Kuroki, 2015, USA[57]	R	122 endometrial cancer patients (0%, 65.9)	Not stated	Psoas L3	CSA (CT)	• CSA-based sarcopenia was not associated with LOS or 90-day readmission rate
Lanza, 2020, Italy[58]	R	142 HCC patients who received bland transarterial embolization (77%, 73)	27 months	L3 (all muscles)	SMI (CT)	• No significant difference in LOS between SMI-based sarcopenic or non-sarcopenic patients
Looijaard, 2019, the Netherlands[63]	R	378 colorectal cancer patients (60.3, 73.4)	5.3 years	L3 (all muscles)	MD (CT) SMI (CT)	• LOS: no significant effect of MD or SMI. • Readmission: no significant effect of MD or SMI
Namm, 2017, USA[130]	P	116 undergoing pancreatico-duodenectomy for pancreatic malignancy (53%, 65.5)	33 months	Psoas at L3	MD (CT) TPI (CT)	• No effect of TPI or MD on LOS or 90-day readmission • Higher risk of discharge to nursing facility in low TPI: OR 0.30** and in low MD: OR 0.9*
Shachar, 2017, USA[86]	P	40 metastatic breast cancer patients receiving taxane-based chemotherapy (55)	1.9 years	L3 (all muscles)	MD (CT) SMG (CT)	• Lower MD in hospitalized patients: 23 vs. 32 HU* • Lower SMG in hospitalized patients: 862 vs. 1362*
Souwer, 2019, the Netherlands [92]	P	174 70+year old patients with colorectal cancer (51%, 78)	956 days	Psoas, paraspinal, TA, EO, IO, RA at L3	SMI (CT) MD (CT)	• SMI: o No difference in discharge destination o More readmissions in Q4 vs. Q1: 19 vs. 5%*; OR 1.61* • MD: o No difference in discharge destination or readmission
Sun, 2022, Japan[133)]	R	341 NSCLC patients undergoing lobectomy (59%, 70)	65 months	Pectoralis at T4	PeMI (CT) MD (CT)	• Longer hospital stay in lower CSA/BMI: 8, 8, 7, 6 days** • Longer hospital stay in lower MD: 8, 8, 7, 7 days* • Longer hospital stay in lower PeMI: 8, 8, 7, 6 days**
Suzuki, 2016, Japan[94]	R	90 stage I NSCLC patients undergoing complete resection (57.8%, 68.7)	Not stated	L3 (all muscles)	SMI (CT)	• SMI-defined sarcopenia had no significant effect on hospital stay
Van der Zanden, 2021, the Netherlands [102]	R	213 women ≥ 70 years old receiving surgery for primary, advanced stage ovarian cancer (0%, 75.9)	Not stated	L3 (all muscles)	MD (CT)	• MD had no significant effect on extended LOS (> 14 days) or rehospitalization • Higher risk of discharge to care facility in low MD group: 20 vs. 7.6%*
Van Vugt, 2018, the Netherlands [104]	P	816 stage I-III colorectal cancer patients (54%, 70)	76.5 months	L3 (all muscles)	SMI (CT) MD (CT)	• Longer LOS in patients with low SMI* • Longer LOS in patients with low MD**
Williams, 2021, USA[107]	R	142 multiple myeloma patients undergoing autologous stem cell transplantation (65%, 61.6)	27-33 months	Psoas at L3	MD (CT)	• No difference in ICU transfer, total days in hospital, discharge to rehabilitation facility, or unplanned hospitalization
Youn, 2021, Canada[163]	R	44 metastatic myeloma patients treated with Nivolumab (57%, 57)	Not stated	L3 (all muscles)	MD (CT)	• MD did not have a significant effect on hospitalization rates

** = P<0.05; ** = P<0.01. AUC = area under the curve; BIA = bioelectrical impedance analysis; BMI = body mass index; CSA = cross-sectional area; CT = computed tomography; EO = external oblique; HCC = hepatocellular carcinoma; ICU = intensive care unit; IO = internal oblique; L3 = lumbar vertebra 3; LOS = length of stay; MD = muscle density; NS = not significant; NSCLC = non small cell lung cancer; OR = odds ratio; P = prospective; PeMI = pectoralis muscle index; PS = psoas muscles; PvMI = paravertebral muscle index; R = retrospective; Q = quartile; RA = rectus abdominis; SMG = skeletal muscle gauge; SMI = skeletal muscle index; SMM = skeletal muscle mass; T4 = thoracic vertebra 4; T5 = thoracic vertebra 5; T12 = thoracic vertebra 12; TA = transverse abdominis; TPI = total psoas index; TPN = total parenteral nutrition; vs. = versus*

Table 9. Characteristics and results of included studies on quality of life in oncology patients.

First author, year, country	Design	Population (%men, mean age (years))	Mean follow-up	Investigated muscle(s) or region	Muscle parameters + imaging method	Statistical results
Cortellini, 2020, Italy[161]	R	100 patients with advanced cancer receiving anti-PD-1/PD-L1 checkpoint inhibitors (67%, 66)	20.3 months	L3 (all muscles)	SMI (CT)	• Lower SMI was associated with lower ECOG-PS*
Dolan, 2020, UK[137]	P	523 patients with advanced cancer (51%, >65)	10.5 months	L3 (all muscles)	MD (CT) SMI (CT)	• ECOG-PS was associated with low SMI: OR 1.53* • ECOG-PS was associated with low MD: OR 2.01**
Shaver, 2021, USA[138]	R	163 head and neck cancer patients (82%, 61.8)	Not stated	L3 (all muscles)	MD (CT)	• Men with myosteatosis had lower physical QOL score after 1 year: 48.84 points lower* • Men with myosteatosis had lower total QOL score after 1 year: 57.57 points lower*

** = P<0.05; ** = P<0.01. CT = computed tomography; ECOG- PS = Eastern Cooperative Oncology Group Performance Status; L3 = lumbar vertebra 3; MD = muscle density; OR = odds ratio; P = prospective; PD-1 = Programmed Cell Death Protein 1; PD-L1 = Programmed Cell Death Ligand 1; QOL = quality of life; R = retrospective; SMI = skeletal muscle index*

significantly associated with better OS, with HR ranging from 1.09 to 2.16 (median 2.36) in the six articles that mentioned HR. Concerning the CT-based psoas muscle index (PMI), 3/6 (50%) showed a significant beneficial association of higher PMI on OS (median HR 2.33). Only one study used EI, but no significant effect on survival was shown.

Progression-free survival

Progression-free survival (PFS) is measured as the time from randomisation until either disease progression or death and was discussed in 39 original studies. Of the 31 studies on CT-based SMI and SMI-defined sarcopenia, 45% showed a significant impact, with HR ranging from 1.16 to 4.40 (median 1.82). Twenty-seven articles measured the effect of MD on PFS. In 16 studies (59%), significant results were seen. Of these, 13 favoured high MD with HR for low density ranging from 1.50 to 2.42 (median 1.99). Three however found higher PFS in low MD, with HR ranging from 0.49 to 0.68. Seven studies used CSA, but only two had significant results (28%), with a mean HR of 3.38. PMI was described in three articles, with significant benefit of higher PMI in two. One out of three articles showed a positive effect of SMG with HR of 1.10, but no significant correlations were found in two out of three articles. Only one article described effect of MT, with a HR of 4.57.

Cancer-specific survival

Cancer-specific survival (CSS) is the time from randomization until death caused by the index cancer. Only three articles searched for the effect on CSS. All three investigated SMI, with significant results in two of them (HR 1.74 and 2.07). One article did not find a significant correlation with MD, PMI nor MT.

Chemotoxicity

Twenty articles were included in the chemotoxicity search, 18 of them were retrospective. Seventeen investigated SMI, 13 MD, three SMG and four CSA. Of the 17 articles investigating SMI, 10 showed a significant relation with chemotoxicity (59%), with lower SMI appearing to be associated with dose-limiting toxicity or showing less chance of chemotherapy completion. Other studies showed more grade three or higher chemotoxicity, more leukopenia or more neuropathy. One study found only an effect on acute toxicities and not on chronic toxicity. Of those reporting MD, 7 out of 13 (54%) reported an association with chemotoxicity rates: 6/7 demonstrated a higher rate of adverse events, grade 3 or higher chemotoxicity and less chemotherapy completion in the presence of low MD or myosteatosis. Conversely, one article showed higher immune-related adverse events in high MD, probably because of better immune response. Lower SMG showed more adverse events and toxicity in 2/3 articles. All four articles showed that lower CSA gave rise to earlier drug-lowering toxicity, more grade three or higher toxicity and more acute and chronic toxicity. All results are shown in Table 5[25,30,38,40,41,43,46,48,55,63,65,70,86,114-120].

Surgical outcomes in oncology

Results of surgical outcomes can be found in Table 6 [25,27,29,34,39,49-51,57,58,63,83,84,92,94,102-104,107,121-133]. Thirty-two articles on surgical outcomes were included, of which 10 are prospective (31%). Eighteen described SMI. Seven (39%) saw a beneficial effect of a higher SMI, with lower risk of overall complications, respiratory failure, and infectious complications. Fourteen out of 17 MD studies (82%) noted that low MD gave rise to more postoperative complications, and more infectious, haemorrhagic, and cardiovascular problems. Half of the 8 articles on CSA showed that a lower CSA was related to more complications and respiratory failure. Low SMM showed more ileus and infectious and cardiac problems in 2 studies.

Response to oncologic treatment

Results generally favoured improved response with higher muscle parameters. Twelve articles described muscle parameters in relation to the chance of response to oncologic treatment (11 retrospective). Nine described the effect of SMI, of which only 1 found a significant effect on local progression (HR 0.89). Out of 8 studies, 3 found relevant correlations between MD and treatment response, with higher MD rendering a higher chance of IL2- response, higher treatment response and higher pathological response. SMG could predict time to treatment failure in 1 out of 2 articles. For CSA, 1 out of 2 articles found a higher pathological response in patients with greater CSA (OR 1.50). The one article on MT could not show a significant effect. These results are summarized in Table 7 [25,27,30,36,48,55,74,86,115,134-136].

Length of stay and rehospitalization.

On this topic, 20 articles were retained (15 retrospective), which can be found in Table 8 [25,27,29,39,57,58,63,86,92,94,102,104,107,114,123,125-127,130,133]. For SMI, 7 investigated the effect on length of stay, of which only 1 found longer hospitalization duration in lower SMI. In 1 out of 2 articles, a higher rate of rehospitalization was found in those with low SMI. Half of the articles (56%) which looked at MD in relation to length of stay found that those with lower MD had a longer length of stay. One in 6 saw more rehospitalization in low MD patients. People with more hospitalizations had lower SMG. Patients with lower psoas or pectoralis muscle index had an increased risk of longer hospital stay in 4 out of 5 articles. Similar results were found for CSA in 1 out of 2 articles. One article described that patients with lower SMM had to stay longer in the hospital. Two studies looked at discharge destination in relation to muscle parameters in oncological patients, one of which found higher discharge rates to a care facility seen in those with lower MD or total psoas index.

Quality of life in oncology

Finally, quality of life was assessed in 3 articles (Table 9)[40,137,138]. Lower SMI was associated with lower ECOG-PS in 2 articles. MD was associated with lower ECOG-PS and lower total and physical quality of life scores.

Discussion

This study aimed to provide a high-quality, updated overview on the current knowledge on association of muscle parameters and certain clinical outcomes in oncology. Second, we wanted to give insight in the current literature regarding muscle parameters assessable in radiology and oncological outcomes.

In this systematic review, 117 articles were included and divided into six outcome categories: survival, chemotoxicity, surgical outcomes, treatment response, length of stay, and health-associated quality of life. Although the search included CT, MRI, US, BIA and DXA, most studies used CT to measure muscle parameters. This is because most patients with cancer have already undergone CT scans for staging. US and MRI are sometimes used in head and neck oncology because often MRI is superior to CT to distinguish different structures. Quantitative measurements included were mostly SMI, but also MT or CSA. MD was used as a qualitative parameter.

Six different cancer outcomes were described, of which survival is the most frequently investigated. In older studies, OS was mainly used. However, since this endpoint is more expensive and time-consuming, a shift towards PFS and CSS was seen in studies concerning pharmacologic treatment in oncology research. Quantitative muscle parameters were clearly associated with survival, as were qualitative parameters in a substantial number of studies. Although SMG can be seen as a good combination of quantitative and qualitative characteristics, it could not show a significant impact in most survival studies. These findings are in concordance with previous systematic reviews and meta-analyses on oncology survival. Ge et al. found significant associations between low SMI and low MD and lower long-term OS in ovarian cancer patients. However, they could not find an association with PFS[139]. In solid tumors, low SMI was associated with worse survival according to a study by Shachar[140]. Aleixo et al. found shorter OS in patients with myosteatosis in different cancer types[141]. A study by Yang et al. measured lower OS and PFS with lower temporal MT in patients with brain tumor[142]. To our knowledge, this is the first systematic review including multiple muscle parameters in different types of cancer.

Chemotoxicity could be predicted by muscle parameters. Low MD, but also low SMI increased the risk of chemotoxicity, with concomitant morbidity and early treatment discontinuation. Until now, dosage of chemotherapy is most frequently guided by body surface area (BSA) since

this has been shown to correlate with blood volume, cardiac output, and renal function. However, patients with similar BSA can have very different distributions of muscle and adipose tissue. This often leads to over- or underdosing of chemotherapy, with reduced survival and increased complications[143]. Therefore, the American Society of Clinical Oncology (ASCO) guidelines suggest using muscle parameters and measures of body composition in drug dosage determination[144]. Using a combination of SMI and MD can therefore be helpful to guide clinicians in their treatment regimen decisions.

Sarcopenia and unfavourable muscle parameters negatively impact outcomes and increase adverse effects in cardiac and abdominal surgery[145,146]. This review found a clear impact of SMI, CSA, and MD in most of the included studies, with lower muscle quantity or quality related to higher postoperative complications. In oncology, a negative influence of sarcopenia on surgical complications and survival is also described[147-150]. Assessing the patients' muscle status could help determining who is suitable for surgical treatment or deciding whether a patient needs more rigorous follow-up for complications after surgery. It can even be helpful to optimize muscle health through preoperative rehabilitation and nutritional interventions to potentially enhance the chances of positive postoperative outcomes and reduce complications.

Objective response rate (ORR), disease control rate (DCR) and local progression (LP) are less well described in current literature. Muscle quality seems to have a better prognostic impact on response than quantitative measurements. However, in a previous study, sarcopenia was associated with lower ORR and DCR in patients treated with Immune Checkpoint Inhibitors[151]. It is probable that body composition often predicts treatment response, since treatment dosages are generally determined by BSA, which does not always reflect differences in body composition. Therefore, people with similar BSA but distinct muscle parameters can suffer from over-or undertreatment, and, thus, a worse therapeutic response[143].

Length of stay and rehospitalization rate can be predicted by lower qualitative or quantitative muscle parameters in half of the investigated articles. Patients with lower muscle quality or quantity often suffer from more surgical complications and toxicity of treatment, which can reduce quality of life and cause an increase in healthcare expenses. Selecting the most suitable therapy for the individual can therefore be a cost-reducing tool for public healthcare systems that can simultaneously – and, more importantly - improve the patients' wellbeing.

Adding to this, prolonging survival should not be the only goal in cancer treatment. Adding quantity of life years is important, but even more so is expanding qualitative time. Unfortunately, very few articles discuss the effect of muscle parameters on the patient's perspective of treatment and life quality. A tendency towards lower quality of life (QOL) in oncological patients with lower muscle quantity and quality is seen, as is previously ascertained in sarcopenia in a general population[152]. Since the patients' perspective and say in their treatment are very important, future studies should be not only focusing on hard end points, but also on the perception of a certain therapy.

The use of muscle parameters in determining the proper treatment dosage and maximising outcomes of oncologic therapy seems promising. Currently, SMI and MD as measured by CT at the level of L3 are the most studied parameters and can be utilized in a large proportion of oncology patients since the majority undergo abdominal CT in oncological staging. In other cancer types that don't include abdominal CT in routine work-up, other muscle parameters can be used. Ultrasound is a promising technique since it is cheap, easy to use and can evaluate both quantitative and qualitative muscle characteristics. More research on this assessment technique is needed to confirm its usability.

Considering that muscle parameters influence survival and other outcomes in cancer patients, it could be helpful to improve the muscle status as early as possible after diagnosis. A systematic review by Rostoft et al. demonstrated that a geriatric assessment can be very helpful in oncological patients, can improve patient-centred outcomes and treatment completion, and can decrease toxicity and other complications[153]. Survival could potentially be improved with relatively simple interventions such as a protein-rich diet and resistance training, in accordance with their effect on mobility, as is proven in the SPRINTT trial[154]. If muscle status can be improved by treating sarcopenia in advance of starting chemotherapy, immune therapy, or surgery, the complications could be reduced, with less treatment dropouts and thus more success of the oncological treatment.

Another point of consideration and for further research can be follow-up of muscle parameters throughout the oncologic treatment trajectory. Oncology treatments have an unfavourable impact on muscle status through both sarcopenia and cachexia. Chemotherapy often leads to anaemia due to its myelotoxic trait, which impairs oxygen transport to the muscles. In addition, therapies such as anthracyclines can lead to myocardial damage and decrease cardiac output or lung damage. Immunosuppressants can cause loss of muscle mass. Chemotherapy-induced nausea and anorexia diminish protein intake. Cancer treatment is often accompanied by inactivity which can lead to secondary sarcopenia[155,156]. Treatment-independent cancer cachexia occurs as well in 80% of patients undergoing cancer treatment and is responsible for 22-30% of cancer-related deaths[157]. This is due to a systemic inflammatory response mediated by cytokines, chemokines and inflammatory mediators released by cancer cells[157]. This decline in muscle quantity and quality can further impair prognosis and necessitate adaptation of treatment. Additional

research is desirable to study the pattern of muscle decline in oncology and in the different treatment options, and to determine how this should influence treatment dosages during therapy. Frequent follow-up of muscle status can then be performed regularly using easily accessible tools such as US.

Cut-off values or ranges for the different muscle parameters still need to be established. The EWGSOP2 did not suggest specific values for sarcopenia by measurement via CT, MRI, or US. For SMI, multiple cut-off values have been proposed, but without standard values it remains difficult to assess studies and guide practitioners to adapt therapy. The next policy-changing step in oncology would be to detect which (combination of) muscle parameters can be used to determine the individualized dose of chemotherapy or immune therapy instead of BSA. With gender-and age-specific cut-offs, an algorithm for treatment could be made. Frail patients often suffer more from the proposed therapy than from the cancer itself. The ideal range of the muscle parameters could then be an additional parameter to be considered in treatment decision, in order to prevent a potentially harmful therapeutic persistence.

Several strengths of this systematic review should be highlighted. First, this is the first systematic review investigating all muscle parameters measurable by CT, MRI, DXA, and US. It is not limited to a specific cancer type. The review did not only search for evidence about survival, but also other clinically meaningful outcome measures in an oncological setting, showing the advantages of measuring muscle mass and its parameters. This review can certainly help the field of oncology stepping away from the outdated BSA-based regimens and going towards more personalized, patient-tailored treatment plans, and can endorse the use of geriatric assessment and pretreatment interventions to improve muscle. Certain limitations can be mentioned. The extent of the study, including a heterogeneous group of cancer types, treatment options and macroscopic muscle measurements could influence outcomes. As there is a clear tendency towards worse outcomes with lower muscle status, all patients should be screened for this underlying condition, regardless of the cancer type. Another point of consideration is that different studies use different cut-off values for SMI to establish the presence of low muscle mass. Finally, the review aimed to be as inclusive and comprehensive as possible and included several definitions of sarcopenia in the studies retrieved. Some of these studies were not recent and did not follow the most updated standard definitions (EWGSOP2, AWGSOP, NIH, etc.), but previous or unstandardized definitions, which considered the use of muscle mass alone for the term sarcopenia[158]. Due to this, it is possible that some of the studies included were not actually measuring sarcopenia, but low quality or quantity of muscle mass instead. Therefore, they were actually measuring alternative muscle diseases or nutrition-related disorders which are also characterized and involve muscle issues, such as malnutrition, frailty, or importantly within this population, cachexia[159]. Although this could have repercussions on the comparability of the studies, this was not the set-up of this review.

Conclusion

Both qualitative and quantitative muscle parameters can be predictive for cancer survival, surgery outcomes, chemotoxicity, treatment response, length of stay and quality of life. It is strongly advised to start including muscle measurements in oncological treatment plans. This can help to determine who is suitable for a certain treatment and help identify patients who need more rigorous follow-up during their treatment. Furthermore, people could receive personalized pre-treatment plans including rehabilitation and nutritional support in order to enhance their outcomes and minimize the risk of complications. Further research is needed to clarify at which cut-off points better outcomes could be reached.

Authors' contributions

Sophie Bastijns wrote the manuscript. Charlotte Beaudart performed the article search and provided statistical support. Sophie Bastijns, Blanca Alabadi, Thiago Gonzalez Barbosa-Silva, Kristoffer Brockhattingen, Scott Lamers, Karolina Piotrowicz, Carly Welch, and Stany Perkisas participated in the article selection and assessment. Blanca Alabadi, Thiago Gonzalez Barbosa-Silva, Kristoffer Brockhattingen, Scott Lamers, Karolina Piotrowicz, Carly Welch, Anne-Marie De Cock, and Stany Perkisas reviewed the manuscript. All authors read and approved the final version of the manuscript.

Acknowledgements

We wish to thank the following individuals for their contribution in data collection and article review: Femke Ariën, David Beckwée, Florence Benoit, Justin Chew, Olgun Deniz, Katleen Jegers, Meltem Halil, Suzy Hope, Nina Lefeber, Magdalena Malek, Dolores Sanchez-Rodriguez, Aldo Scafoglieri, Kate Taylor, Jona Van den Broeck, Daisy Wilson, Tilo Wünsch

References

1. Health OW. Cancer. 2022.
2. Swaminathan V, Audisio R. Cancer in older patients: an analysis of elderly oncology. Ecancermedicalscience. 2012;6:243.
3. Botta L, Dal Maso L, Guzzinati S, Panato C, Gatta G, Trama A, et al. Changes in life expectancy for cancer patients over time since diagnosis. J Adv Res. 2019;20:153-9.
4. Aversa Z, Costelli P, Muscaritoli M. Cancer-induced muscle wasting: latest findings in prevention and treatment. Ther Adv Med Oncol. 2017;9(5):369-82.
5. Cawthon PM, Visser M, Arai H, Ávila-Funes JA, Barazzoni R, Bhasin S, et al. Defining terms commonly used in sarcopenia research: a glossary proposed by the Global Leadership in Sarcopenia (GLIS) Steering Committee. European Geriatric

Medicine. 2022;13(6):1239-44.
6. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyere O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16-31.
7. Peterson SJ, Mozer M. Differentiating Sarcopenia and Cachexia Among Patients With Cancer. Nutr Clin Pract. 2017;32(1):30-9.
8. Ali S, Garcia JM. Sarcopenia, Cachexia and Aging: Diagnosis, Mechanisms and Therapeutic Options - A Mini-Review. Gerontology. 2014;60(4):294-305.
9. Bahat G, Turkmen BO, Aliyev S, Catikkas NM, Bakir B, Karan MA. Cut-off values of skeletal muscle index and psoas muscle index at L3 vertebra level by computerized tomography to assess low muscle mass. Clin Nutr. 2021;40(6):4360-5.
10. Chianca V, Albano D, Messina C, Gitto S, Ruffo G, Guarino S, et al. Sarcopenia: imaging assessment and clinical application. Abdom Radiol (NY). 2022;47(9):3205-16.
11. Ceniccola GD, Castro MG, Piovacari SMF, Horie LM, Correa FG, Barrere APN, et al. Current technologies in body composition assessment: advantages and disadvantages. Nutrition. 2019;62:25-31.
12. Lees MJ, Wilson OJ, Hind K, Ispoglou T. Muscle quality as a complementary prognostic tool in conjunction with sarcopenia assessment in younger and older individuals. Eur J Appl Physiol. 2019;119(5):1171-81.
13. Cawthon PM, Fox KM, Gandra SR, Delmonico MJ, Chiou CF, Anthony MS, et al. Do muscle mass, muscle density, strength, and physical function similarly influence risk of hospitalization in older adults? J Am Geriatr Soc. 2009;57(8):1411-9.
14. Weinberg MS, Shachar SS, Muss HB, Deal AM, Popuri K, Yu H, et al. Beyond sarcopenia: Characterization and integration of skeletal muscle quantity and radiodensity in a curable breast cancer population. Breast J. 2018;24(3):278-84.
15. Petermann-Rocha F, Balntzi V, Gray SR, Lara J, Ho FK, Pell JP, et al. Global prevalence of sarcopenia and severe sarcopenia: a systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2022;13(1):86-99.
16. Beaudart C, Zaaria M, Pasleau F, Reginster JY, Bruyere O. Health Outcomes of Sarcopenia: A Systematic Review and Meta-Analysis. PLoS One. 2017;12(1):e0169548.
17. Williams GR, Dunne RF, Giri S, Shachar SS, Caan BJ. Sarcopenia in the Older Adult With Cancer. J Clin Oncol. 2021;39(19):2068-78.
18. Ligibel JA, Schmitz KH, Berger NA. Sarcopenia in aging, obesity, and cancer. Transl Cancer Res. 2020;9(9):5760-71.
19. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
20. Morrison A, Polisena J, Husereau D, Moulton K, Clark M, Fiander M, et al. The effect of English-language restriction on systematic review-based meta-analyses: a systematic review of empirical studies. Int J Technol Assess Health Care. 2012;28(2):138-44.
21. Dobrescu AI, Nussbaumer-Streit B, Klerings I, Wagner G, Persad E, Sommer I, et al. Restricting evidence syntheses of interventions to English-language publications is a viable methodological shortcut for most medical topics: a systematic review. J Clin Epidemiol. 2021;137:209-17.
22. Abbass T, Dolan RD, MacLeod N, Horgan PG, Laird BJ, McMillan DC. Comparison of the prognostic value of MUST, ECOG-PS, mGPS and CT derived body composition analysis in patients with advanced lung cancer. Clin Nutr ESPEN. 2020;40:349-56.
23. Abe H, Takei K, Uematsu T, Tokura Y, Suzuki I, Sakamoto K, et al. Significance of sarcopenia as a prognostic factor for metastatic urothelial carcinoma patients treated with systemic chemotherapy. Int J Clin Oncol. 2018;23(2):338-46.
24. Akce M, Liu Y, Zakka K, Martini DJ, Draper A, Alese OB, et al. Impact of Sarcopenia, BMI, and Inflammatory Biomarkers on Survival in Advanced Hepatocellular Carcinoma Treated With Anti-PD-1 Antibody. Am J Clin Oncol. 2021;44(2):74-81.
25. Al Khaldi M, Fellouah M, Drolet P, Côté J, Trilling B, Brind'Amour A, et al. The Impact of Computed Tomography Measurements of Sarcopenia on Postoperative and Oncologic Outcomes in Patients Undergoing Cytoreductive Surgery and Hyperthermic Intraperitoneal Chemotherapy. Current Oncology. 2022;29(12):9314-24.
26. Antoun S, Lanoy E, Iacovelli R, Albiges-Sauvin L, Loriot Y, Merad-Taoufik M, et al. Skeletal muscle density predicts prognosis in patients with metastatic renal cell carcinoma treated with targeted therapies. Cancer. 2013;119(18):3377-84.
27. Arayne AA, Gartrell R, Qiao J, Baird PN, Yeung JM. Comparison of CT derived body composition at the thoracic T4 and T12 with lumbar L3 vertebral levels and their utility in patients with rectal cancer. BMC Cancer. 2023;23(1):56.
28. Arien F, Baitar A, Perkisas S, Vandewoude M, De Cock AM. The association between muscle mass and the degree of myosteatosis of the psoas muscle and mortality in older patients with cancer. J Geriatr Oncol. 2021;12(1):85-90.
29. Asai Y, Yamaguchi J, Mizuno T, Onoe S, Watanabe N, Igami T, et al. Impact of preoperative muscle mass and quality on surgical outcomes in patients undergoing major hepatectomy for perihilar cholangiocarcinoma. J Hepatobiliary Pancreat Sci. 2023;30(2):202-11.
30. Bardoscia L, Besutti G, Pellegrini M, Pagano M, Bonelli C, Bonelli E, et al. Impact of low skeletal muscle mass and quality on clinical outcomes in patients with head and neck cancer undergoing (chemo)radiation. Front Nutr. 2022;9:994499.
31. 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(1):107-14.
32. Besutti G, Massaro F, Bonelli E, Braglia L, Casali M, Versari A, et al. Prognostic Impact of Muscle Quantity and Quality and Fat Distribution in Diffuse Large B-Cell Lymphoma Patients. Front Nutr. 2021;8:620696.
33. Bronger H, Hederich P, Hapfelmeier A, Metz S, Noel PB, Kiechle M, et al. Sarcopenia in Advanced Serous Ovarian Cancer. Int J Gynecol Cancer. 2017;27(2):223-32.
34. Chakedis J, Spolverato G, Beal EW, Woelfel I, Bagante F, Merath K, et al. Pre-operative Sarcopenia Identifies Patients at Risk for Poor Survival After Resection of Biliary Tract Cancers. J Gastrointest Surg. 2018;22(10):1697-708.
35. Charette N, Vandeputte C, Ameye L, Bogaert CV, Krygier J, Guiot T, et al. Prognostic value of adipose tissue and muscle mass in advanced colorectal cancer: a post hoc analysis of two non-randomized phase II trials. BMC Cancer. 2019;19(1):134.
36. Cho A, Hennenberg J, Untersteiner H, Hirschmann D, Gatterbauer B, Zochbauer-Muller S, et al. Influence of temporal muscle thickness on the outcome of radiosurgically treated patients with brain metastases from non-small cell lung cancer. J Neurosurg. 2022:1-7.
37. Chu MP, Lieffers J, Ghosh S, Belch AR, Chua NS, Fontaine A, et al. Skeletal muscle radio-density is an independent predictor of response and outcomes in follicular lymphoma treated with chemoimmunotherapy. PLoS One. 2015;10(6):e0127589.
38. Chu MP, Li Y, Ghosh S, Sass S, Smylie M, Walker J, et al. Body

composition is prognostic and predictive of ipilimumab activity in metastatic melanoma. Journal of Cachexia, Sarcopenia and Muscle. 2020;11(3):748-55.
39. Cinar HU, Celik B, Taskin G, Ince O. Impact of preoperative computed tomography-determined quantity and quality of skeletal muscle on survival after resected non-small cell lung carcinoma. Eur J Surg Oncol. 2022;48(9):1937-46.
40. Cortellini A, Bozzetti F, Palumbo P, Brocco D, Di Marino P, Tinari N, et al. Weighing the role of skeletal muscle mass and muscle density in cancer patients receiving PD-1/PD-L1 checkpoint inhibitors: a multicenter real-life study. Sci Rep. 2020;10(1):1456.
41. Cushen SJ, Power DG, Teo MY, MacEneaney P, Maher MM, McDermott R, et al. Body Composition by Computed Tomography as a Predictor of Toxicity in Patients With Renal Cell Carcinoma Treated With Sunitinib. Am J Clin Oncol. 2017;40(1):47-52.
42. DeFilipp Z, Troschel FM, Qualls DA, Li S, Kuklinski MW, Kempner ME, et al. Evolution of Body Composition Following Autologous and Allogeneic Hematopoietic Cell Transplantation: Incidence of Sarcopenia and Association with Clinical Outcomes. Biol Blood Marrow Transplant. 2018;24(8):1741-7.
43. Dijksterhuis WPM, Pruijt MJ, van der Woude SO, Klaassen R, Kurk SA, van Oijen MGH, et al. Association between body composition, survival, and toxicity in advanced esophagogastric cancer patients receiving palliative chemotherapy. J Cachexia Sarcopenia Muscle. 2019;10(1):199-206.
44. Ferraro V, Thormann M, Hinnerichs M, Pech M, Wolleschak D, Mougiakakos D, et al. Sarcopenia does not predict outcome in patients with CNS lymphoma undergoing systemic therapy. Oncol Lett. 2022;24(4):355.
45. Furtner J, Nenning KH, Roetzer T, Gesperger J, Seebrecht L, Weber M, et al. Evaluation of the Temporal Muscle Thickness as an Independent Prognostic Biomarker in Patients with Primary Central Nervous System Lymphoma. Cancers (Basel). 2021;13(3).
46. Ganju RG, TenNapel M, Spoozak L, Chen AM, Hoover A. The impact of skeletal muscle abnormalities on tolerance to adjuvant chemotherapy and radiation and outcome in patients with endometrial cancer. J Med Imaging Radiat Oncol. 2020;64(1):104-12.
47. Golder AM, Sin LKE, Alani F, Alasadi A, Dolan R, Mansouri D, et al. The relationship between the mode of presentation, CT-derived body composition, systemic inflammatory grade and survival in colon cancer. J Cachexia Sarcopenia Muscle. 2022;13(6):2863-74.
48. Haehl E, Alvino L, Ruhle A, Zou J, Fabian A, Grosu AL, et al. Sarcopenia as a Prognostic Marker in Elderly Head and Neck Squamous Cell Carcinoma Patients Undergoing (Chemo-) Radiation. Cancers (Basel). 2022;14(22).
49. Hirai T, Kobayashi H, Okuma T, Ishibashi Y, Ikegami M, Ohki T, et al. Skeletal muscle measurements predict surgical wound complications but not overall survival in patients with soft tissue sarcoma. Jpn J Clin Oncol. 2020;50(10):1168-74.
50. Huang DD, Yu DY, Song HN, Wang WB, Luo X, Wu GF, et al. The relationship between the GLIM-defined malnutrition, body composition and functional parameters, and clinical outcomes in elderly patients undergoing radical gastrectomy for gastric cancer. Eur J Surg Oncol. 2021;47(9):2323-31.
51. Huang DD, Wu GF, Luo X, Song HN, Wang WB, Liu NX, et al. Value of muscle quality, strength and gait speed in supporting the predictive power of GLIM-defined malnutrition for postoperative outcomes in overweight patients with gastric cancer. Clin Nutr. 2021;40(6):4201-8.
52. Huq S, Khalafallah AM, Ruiz-Cardozo MA, Botros D, Oliveira LAP, Dux H, et al. A novel radiographic marker of sarcopenia with prognostic value in glioblastoma. Clin Neurol Neurosurg. 2021;207:106782.
53. Jeon YW, Park HS, Ko Y, Sung YS, Shim BY, Suh YJ, et al. Intermuscular fat density as a novel prognostic factor in breast cancer patients treated with adjuvant chemotherapy. Breast Cancer Res Treat. 2021;189(3):759-68.
54. Kim EY, Kim YS, Park I, Ahn HK, Cho EK, Jeong YM. Prognostic Significance of CT-Determined Sarcopenia in Patients with Small-Cell Lung Cancer. J Thorac Oncol. 2015;10(12):1795-9.
55. Kim IH, Choi MH, Lee IS, Hong TH, Lee MA. Clinical significance of skeletal muscle density and sarcopenia in patients with pancreatic cancer undergoing first-line chemotherapy: a retrospective observational study. BMC Cancer. 2021;21(1):77.
56. Kim YI, Shin JY, Yang SH, Kim HH, Shim BY, Ahn S. Association between Temporal Muscle Thickness and Overall Survival in Non-Small Cell Lung Cancer Patients with Brain Metastasis. Curr Oncol. 2022;29(9):6463-71.
57. Kuroki LM, Mangano M, Allsworth JE, Menias CO, Massad LS, Powell MA, et al. Pre-operative assessment of muscle mass to predict surgical complications and prognosis in patients with endometrial cancer. Ann Surg Oncol. 2015;22(3):972-9.
58. Lanza E, Masetti C, Messana G, Muglia R, Pugliese N, Ceriani R, et al. Sarcopenia as a predictor of survival in patients undergoing bland transarterial embolization for unresectable hepatocellular carcinoma. PLoS One. 2020;15(6):e0232371.
59. Lee JS, Kim YS, Kim EY, Jin W. Prognostic significance of CT-determined sarcopenia in patients with advanced gastric cancer. PLoS One. 2018;13(8):e0202700.
60. Leone R, Sferruzza G, Calimeri T, Steffanoni S, Conte GM, De Cobelli F, et al. Quantitative muscle mass biomarkers are independent prognosis factors in primary central nervous system lymphoma: The role of L3-skeletal muscle index and temporal muscle thickness. Eur J Radiol. 2021;143:109945.
61. Li Q, Zhang L, Hou ZH, Zhao DX, Li JB, Zhang S, et al. High Visceral Adipose Tissue Density Correlates With Unfavorable Outcomes in Patients With Intermediate-Stage Hepatocellular Carcinoma Undergoing Transarterial Chemoembolization. Front Cell Dev Biol. 2021;9:710104.
62. Liu F, Xing D, Zha Y, Wang L, Dong W, Li L, et al. Predictive Value of Temporal Muscle Thickness Measurements on Cranial Magnetic Resonance Images in the Prognosis of Patients With Primary Glioblastoma. Front Neurol. 2020;11:523292.
63. Looijaard S, Meskers CGM, Slee-Valentijn MS, Bouman DE, Wymenga ANM, Klaase JM, et al. Computed Tomography-Based Body Composition Is Not Consistently Associated with Outcome in Older Patients with Colorectal Cancer. Oncologist. 2020;25(3):e492-e501.
64. Loumaye A, de Barsy M, Nachit M, Lause P, van Maanen A, Trefois P, et al. Circulating Activin A predicts survival in cancer patients. J Cachexia Sarcopenia Muscle. 2017;8(5):768-77.
65. Martin D, von der Grun J, Rodel C, Fokas E. Sarcopenia Is Associated With Hematologic Toxicity During Chemoradiotherapy in Patients With Anal Carcinoma. Front Oncol. 2020;10:1576.
66. Maurits JSF, Sedelaar JPM, Mulders PFA, Aben KKH, Kiemeney L, Vrieling A. Skeletal muscle radiodensity and visceral adipose tissue index are associated with survival in renal cell cancer - A multicenter population-based cohort study. Clin Nutr. 2022;41(1):131-43.
67. McGoldrick DM, Yassin Alsabbagh A, Shaikh M, Pettit L, Bhatia

SK. Masseter muscle defined sarcopenia and survival in head and neck cancer patients. Br J Oral Maxillofac Surg. 2022;60(4):454-8.
68. Mi E, Mauricaite R, Pakzad-Shahabi L, Chen J, Ho A, Williams M. Deep learning-based quantification of temporalis muscle has prognostic value in patients with glioblastoma. Br J Cancer. 2022;126(2):196-203.
69. Miller BS, Ignatoski KM, Daignault S, Lindland C, Doherty M, Gauger PG, et al. Worsening central sarcopenia and increasing intra-abdominal fat correlate with decreased survival in patients with adrenocortical carcinoma. World J Surg. 2012;36(7):1509-16.
70. Miyamoto Y, Hiyoshi Y, Akiyama T, Kiyozumi Y, Eto K, Yohei N, et al. Low Skeletal Muscle Mass before Salvage-Line Chemotherapy Is a Poor Prognostic Factor in Patients with Refractory Metastatic Colorectal Cancer. Digestion. 2019;99(1):79-85.
71. Muglia R, Simonelli M, Pessina F, Morenghi E, Navarria P, Persico P, et al. Prognostic relevance of temporal muscle thickness as a marker of sarcopenia in patients with glioblastoma at diagnosis. Eur Radiol. 2021;31(6):4079-86.
72. Muñoz-Rodríguez J, Domínguez A, Rosado MA, Centeno C, Parejo V, Costa-Trachsel I, et al. Effect of muscle density in patients with metastatic prostate cancer administered androgen deprivation therapy. Endocrinología, Diabetes y Nutrición (English ed). 2021;68(2):92-8.
73. Nishikawa D, Hanai N, Suzuki H, Koide Y, Beppu S, Hasegawa Y. The Impact of Skeletal Muscle Depletion on Head and Neck Squamous Cell Carcinoma. ORL J Otorhinolaryngol Relat Spec. 2018;80(1):1-9.
74. Nishioka N, Naito T, Notsu A, Mori K, Kodama H, Miyawaki E, et al. Unfavorable impact of decreased muscle quality on the efficacy of immunotherapy for advanced non-small cell lung cancer. Cancer Med. 2021;10(1):247-56.
75. Nozawa H, Emoto S, Murono K, Shuno Y, Kawai K, Sasaki K, et al. Change in skeletal muscle index and its prognostic significance in patients who underwent successful conversion therapy for initially unresectable colorectal cancer: observational study. Therap Adv Gastroenterol. 2020;13:1756284820971197.
76. Omarini C, Palumbo P, Pecchi A, Draisci S, Balduzzi S, Nasso C, et al. Predictive Role Of Body Composition Parameters In Operable Breast Cancer Patients Treated With Neoadjuvant Chemotherapy. Cancer Manag Res. 2019;11:9563-9.
77. Ozeki N, Kawaguchi K, Fukui T, Nakamura S, Hakiri S, Mori S, et al. Psoas muscle mass in patients undergoing lung cancer surgery: a prognostic difference between squamous cell carcinoma and adenocarcinoma. Int J Clin Oncol. 2020;25(5):876-84.
78. Özer EE, Kırlı Bölükbaş M, Nalbant MO, Soydemir GP, Figen M, Koçak Uzel E. Can Temporal Muscle Thickness Be a New Prognostic Factor for De Novo Glioblastoma? Bakirkoy Tip Dergisi / Medical Journal of Bakirkoy. 2022;18(3):303-9.
79. Peng YC, Wu CH, Tien YW, Lu TP, Wang YH, Chen BB. Preoperative sarcopenia is associated with poor overall survival in pancreatic cancer patients following pancreaticoduodenectomy. Eur Radiol. 2021;31(4):2472-81.
80. Pereira AZ, de Almeida-Pitito B, Eugenio GC, Ruscitto do Prado R, Silva CC, Hamerschlak N. Impact of Obesity and Visceral Fat on Mortality in Hematopoietic Stem Cell Transplantation. JPEN J Parenter Enteral Nutr. 2021;45(7):1597-603.
81. Phan EN, Thorpe SW, Wong FS, Saiz AM, Taylor SL, Canter RJ, et al. Opportunistic muscle measurements on staging chest CT for extremity and truncal soft tissue sarcoma are associated with survival. J Surg Oncol. 2020;122(5):869-76.
82. Rier HN, Kharagjitsing H, van Rosmalen J, van Vugt J, Westerweel PE, de Jongh E, et al. Prognostic impact of low muscle mass and low muscle density in patients with diffuse large B-cell lymphoma. Leuk Lymphoma. 2020;61(7):1618-26.
83. Rutten IJ, Ubachs J, Kruitwagen RF, van Dijk DP, Beets-Tan RG, Massuger LF, et al. The influence of sarcopenia on survival and surgical complications in ovarian cancer patients undergoing primary debulking surgery. Eur J Surg Oncol. 2017;43(4):717-24.
84. Sabel MS, Lee J, Cai S, Englesbe MJ, Holcombe S, Wang S. Sarcopenia as a prognostic factor among patients with stage III melanoma. Ann Surg Oncol. 2011;18(13):3579-85.
85. Sanchez-Torralvo FJ, Ruiz-Garcia I, Contreras-Bolivar V, Gonzalez-Almendros I, Ruiz-Vico M, Abuin-Fernandez J, et al. CT-Determined Sarcopenia in GLIM-Defined Malnutrition and Prediction of 6-Month Mortality in Cancer Inpatients. Nutrients. 2021;13(8).
86. Shachar SS, Deal AM, Weinberg M, Nyrop KA, Williams GR, Nishijima TF, et al. Skeletal Muscle Measures as Predictors of Toxicity, Hospitalization, and Survival in Patients with Metastatic Breast Cancer Receiving Taxane-Based Chemotherapy. Clin Cancer Res. 2017;23(3):658-65.
87. Shaver AL, Platek ME, Singh AK, Ma SJ, Farrugia M, Wilding G, et al. Effect of musculature on mortality, a retrospective cohort study. BMC Cancer. 2022;22(1):688.
88. Sheikhbahaei S, Reyes DK, Rowe SP, Pienta KJ. CT-based assessment of body composition following neoadjuvant chemohormonal therapy in patients with castration-naive oligometastatic prostate cancer. Prostate. 2021;81(2):127-34.
89. Sjoblom B, Gronberg BH, Wentzel-Larsen T, Baracos VE, Hjermstad MJ, Aass N, et al. Skeletal muscle radiodensity is prognostic for survival in patients with advanced non-small cell lung cancer. Clin Nutr. 2016;35(6):1386-93.
90. Song EJ, Lee CW, Jung SY, Kim BN, Lee KS, Lee S, et al. Prognostic impact of skeletal muscle volume derived from cross-sectional computed tomography images in breast cancer. Breast Cancer Res Treat. 2018;172(2):425-36.
91. Sutcuoglu O, Erdal ZS, Akdogan O, Celtikci E, Ozdemir N, Ozet A, et al. The possible relation between temporal muscle mass and glioblastoma multiforme prognosis via sarcopenia perspective. Turk J Med Sci. 2023;53(1):413-9.
92. Souwer ET, Moos SI, van Rooden CJ, Bijlsma AY, Bastiaannet E, Steup WH, et al. Physical performance has a strong association with poor surgical outcome in older patients with colorectal cancer. Eur J Surg Oncol. 2020;46(3):462-9.
93. Souza NC, Gonzalez MC, Martucci RB, Rodrigues VD, de Pinho NB, Qureshi AR, et al. Comparative Analysis Between Computed Tomography and Surrogate Methods to Detect Low Muscle Mass Among Colorectal Cancer Patients. JPEN J Parenter Enteral Nutr. 2020;44(7):1328-37.
94. Suzuki Y, Okamoto T, Fujishita T, Katsura M, Akamine T, Takamori S, et al. Clinical implications of sarcopenia in patients undergoing complete resection for early non-small cell lung cancer. Lung Cancer. 2016;101:92-7.
95. Taguchi S, Akamatsu N, Nakagawa T, Gonoi W, Kanatani A, Miyazaki H, et al. Sarcopenia Evaluated Using the Skeletal Muscle Index Is a Significant Prognostic Factor for Metastatic Urothelial Carcinoma. Clin Genitourin Cancer. 2016;14(3):237-43.
96. Takeoka Y, Sakatoku K, Miura A, Yamamura R, Araki T, Seura H, et al. Prognostic Effect of Low Subcutaneous Adipose Tissue on Survival Outcome in Patients With Multiple Myeloma. Clin Lymphoma Myeloma Leuk. 2016;16(8):434-41.

97. Thormann M, Heitmann F, March C, Pech M, Hass P, Surov A, et al. Sarcopenia does not limit overall survival after interstitial brachytherapy for breast cancer liver metastases. J Contemp Brachytherapy. 2022;14(4):364-9.
98. Troschel FM, Kuklinski MW, Knoll SJ, Best TD, Muniappan A, Gaissert HA, et al. Preoperative thoracic muscle area on computed tomography predicts long-term survival following pneumonectomy for lung cancer. Interact Cardiovasc Thorac Surg. 2019;28(4):542-9.
99. Troschel FM, Jin Q, Eichhorn F, Muley T, Best TD, Leppelmann KS, et al. Sarcopenia on preoperative chest computed tomography predicts cancer-specific and all-cause mortality following pneumonectomy for lung cancer: A multicenter analysis. Cancer Med. 2021;10(19):6677-86.
100. Ueki H, Hara T, Okamura Y, Bando Y, Terakawa T, Furukawa J, et al. Association between sarcopenia based on psoas muscle index and the response to nivolumab in metastatic renal cell carcinoma: A retrospective study. Investig Clin Urol. 2022;63(4):415-24.
101. van Baar H, Beijer S, Bours MJL, Weijenberg MP, van Zutphen M, van Duijnhoven FJB, et al. Low radiographic muscle density is associated with lower overall and disease-free survival in early-stage colorectal cancer patients. J Cancer Res Clin Oncol. 2018;144(11):2139-47.
102. van der Zanden V, van Soolingen NJ, Viddeleer AR, Trum JW, Amant F, Mourits MJE, et al. Low preoperative skeletal muscle density is predictive for negative postoperative outcomes in older women with ovarian cancer. Gynecol Oncol. 2021;162(2):360-7.
103. Van Rijssen LB, van Huijgevoort NC, Coelen RJ, Tol JA, Haverkort EB, Nio CY, et al. Skeletal Muscle Quality is Associated with Worse Survival After Pancreatoduodenectomy for Periampullary, Nonpancreatic Cancer. Ann Surg Oncol. 2017;24(1):272-80.
104. van Vugt JLA, Coebergh van den Braak RRJ, Lalmahomed ZS, Vrijland WW, Dekker JWT, Zimmerman DDE, et al. Impact of low skeletal muscle mass and density on short and long-term outcome after resection of stage I-III colorectal cancer. Eur J Surg Oncol. 2018;44(9):1354-60.
105. van Vugt JLA, Gaspersz MP, Vugts J, Buettner S, Levolger S, de Bruin RWF, et al. Low Skeletal Muscle Density Is Associated with Early Death in Patients with Perihilar Cholangiocarcinoma Regardless of Subsequent Treatment. Dig Surg. 2019;36(2):144-52.
106. Von Geldern P, Salas C, Alvayay P, Silva C, de la Maza MP. Nutritional assessment by subjective methods versus computed tomography to predict survival in oncology patients. Nutrition. 2021;84:111006.
107. Williams A, Baruah D, Patel J, Szabo A, Chhabra S, Dhakal B, et al. Prevalence and significance of sarcopenia in multiple myeloma patients undergoing autologous hematopoietic cell transplantation. Bone Marrow Transplant. 2021;56(1):225-31.
108. Xiao LS, Li RN, Cui H, Hong C, Huang CY, Li QM, et al. Use of computed tomography-derived body composition to determine the prognosis of patients with primary liver cancer treated with immune checkpoint inhibitors: a retrospective cohort study. BMC Cancer. 2022;22(1):737.
109. Yamashita S, Iwahashi Y, Miyai H, Iguchi T, Koike H, Nishizawa S, et al. Myosteatosis as a novel prognostic biomarker after radical cystectomy for bladder cancer. Sci Rep. 2020;10(1):22146.
110. Yan OY, Teng HB, Fu SN, Chen YZ, Liu F. Temporal Muscle Thickness is an Independent Prognostic Biomarker in Patients with Glioma: Analysis of 261 Cases. Cancer Manag Res. 2021;13:6621-32.
111. Yesil Cinkir H, Colakoglu Er H. Is temporal muscle thickness a survival predictor in newly diagnosed glioblastoma multiforme? Asia Pac J Clin Oncol. 2020;16(5):e223-e7.
112. yeşil çınkır h. The Prognostic Effects of Temporal Muscle Thickness and Inflammatory-Nutritional Parameters on Survival in Lung Cancer Patients with Brain Metastasis. Turkish Journal of Oncology. 2020.
113. Yokoi K, Tanaka T, Kojo K, Miura H, Yamanashi T, Sato T, et al. Skeletal Muscle Changes Assessed by Preoperative Computed Tomography Images Can Predict the Long-Term Prognosis of Stage III Colorectal Cancer. Ann Gastroenterol Surg. 2022;6(3):386-95.
114. Youn S, Reif R, Chu MP, Smylie M, Walker J, Eurich DT, et al. Myosteatosis is prognostic in metastatic melanoma treated with nivolumab. Clin Nutr ESPEN. 2021;42:348-53.
115. Young AC, Quach HT, Song H, Davis EJ, Moslehi JJ, Ye F, et al. Impact of body composition on outcomes from anti-PD1 +/- anti-CTLA-4 treatment in melanoma. J Immunother Cancer. 2020;8(2).
116. Aleixo GFP, Yu H, Chen YT, Nyrop KA, Louie RJ, Deal AM, et al. Myosteatosis evaluation using erector spinae and psoas muscles to predict adverse events during adjuvant chemotherapy for breast cancer. Breast Cancer Res Treat. 2021;186(2):487-95.
117. Huang X, Lv LN, Zhao Y, Li L, Zhu XD. Is skeletal muscle loss associated with chemoradiotherapy toxicity in nasopharyngeal carcinoma patients? A prospective study. Clin Nutr. 2021;40(1):295-302.
118. Mazzuca F, Onesti CE, Roberto M, Di Girolamo M, Botticelli A, Begini P, et al. Lean body mass wasting and toxicity in early breast cancer patients receiving anthracyclines. Oncotarget. 2018;9(39):25714-22.
119. Phuong A, Marquardt JP, O'Malley R, Holt SK, Laidlaw G, Eagle Z, et al. Changes in skeletal muscle and adipose tissue during cytotoxic chemotherapy for testicular germ cell carcinoma and associations with adverse events. Urol Oncol. 2022;40(10):456 e19- e30.
120. Smit D, Mols F, Bonhof CS, Bours MJL, Vreugdenhil G, Beijer S. Is CT-based body composition associated with long-term chemotherapy-induced peripheral neuropathy in colorectal cancer survivors? Support Care Cancer. 2022;30(7):6071-8.
121. Baker S, Waldrop MG, Swords J, Wang T, Heslin M, Contreras C, et al. Timed Stair-Climbing as a Surrogate Marker for Sarcopenia Measurements in Predicting Surgical Outcomes. J Gastrointest Surg. 2019;23(12):2459-65.
122. Bozkurt G, Elhassan HA, Mahmutoglu AS, Celebi I, McLeod RWJ, Soytas P, et al. Neck Muscle Mass Index as a Predictor of Post-Laryngectomy Wound Complications. Ann Otol Rhinol Laryngol. 2018;127(11):841-7.
123. Fintelmann FJ, Troschel FM, Mario J, Chretien YR, Knoll SJ, Muniappan A, et al. Thoracic Skeletal Muscle Is Associated With Adverse Outcomes After Lobectomy for Lung Cancer. Ann Thorac Surg. 2018;105(5):1507-15.
124. Galli A, Colombo M, Prizio C, Carrara G, Lira Luce F, Paesano PL, et al. Skeletal Muscle Depletion and Major Postoperative Complications in Locally-Advanced Head and Neck Cancer: A Comparison between Ultrasound of Rectus Femoris Muscle and Neck Cross-Sectional Imaging. Cancers (Basel). 2022;14(2).
125. Joglekar S, Asghar A, Mott SL, Johnson BE, Button AM, Clark E, et al. Sarcopenia is an independent predictor of complications following pancreatectomy for adenocarcinoma. J Surg Oncol. 2015;111(6):771-5.
126. Kim EY, Kim SR, Won DD, Choi MH, Lee IK. Multifrequency

Bioelectrical Impedance Analysis Compared With Computed Tomography for Assessment of Skeletal Muscle Mass in Primary Colorectal Malignancy: A Predictor of Short-Term Outcome After Surgery. Nutr Clin Pract. 2020;35(4):664-74.
127. Kim EY, Lee HY, Kim KW, Lee JI, Kim YS, Choi WJ, et al. Preoperative Computed Tomography-Determined Sarcopenia and Postoperative Outcome After Surgery for Non-Small Cell Lung Cancer. Scand J Surg. 2018;107(3):244-51.
128. Lin J, Zhang W, Chen W, Huang Y, Wu R, Chen X, et al. Muscle Mass, Density, and Strength Are Necessary to Diagnose Sarcopenia in Patients With Gastric Cancer. J Surg Res. 2019;241:141-8.
129. Martini K, Chassagnon G, Fournel L, Prieto M, Hoang-Thi TN, Halm N, et al. Sarcopenia as independent risk factor of postpneumonectomy respiratory failure, ARDS and mortality. Lung Cancer. 2020;149:130-6.
130. Namm JP, Thakrar KH, Wang CH, Stocker SJ, Sur MD, Berlin J, et al. A semi-automated assessment of sarcopenia using psoas area and density predicts outcomes after pancreaticoduodenectomy for pancreatic malignancy. J Gastrointest Oncol. 2017;8(6):936-44.
131. Nishigori T, Okabe H, Tanaka E, Tsunoda S, Hisamori S, Sakai Y. Sarcopenia as a predictor of pulmonary complications after esophagectomy for thoracic esophageal cancer. J Surg Oncol. 2016;113(6):678-84.
132. Sengul Aycicek G, Erol T, Unsal P, Deniz O, Abbasoglu O, Halil M. Impact of frailty and ultrasonography-based sarcopenia on the development of postoperative complications in gastrointestinal cancer patients. Turk J Med Sci. 2021;51(3):1261-6.
133. Sun C, Anraku M, Kawahara T, Karasaki T, Konoeda C, Kitano K, et al. Combination of Skeletal Muscle Mass and Density Predicts Postoperative Complications and Survival of Patients With Non-Small Cell Lung Cancer. Ann Surg Oncol. 2022;29(3):1816-24.
134. Chiu CH, Zhang P, Chang AC, Derstine BA, Ross BE, Enchakalody B, et al. Morphomic Factors Associated With Complete Response to Neoadjuvant Therapy in Esophageal Carcinoma. Ann Thorac Surg. 2020;109(1):241-8.
135. Otemuyiwa B, Derstine BA, Zhang P, Wong SL, Sabel MS, Redman BG, et al. Dorsal Muscle Attenuation May Predict Failure to Respond to Interleukin-2 Therapy in Metastatic Renal Cell Carcinoma. Acad Radiol. 2017;24(9):1094-100.
136. Pan Y, Chen Z, Yang L, Wang X, Yi Z, Zhou L, et al. Body Composition Parameters May Be Prognostic Factors in Upper Urinary Tract Urothelial Carcinoma Treated by Radical Nephroureterectomy. Front Oncol. 2021;11:679158.
137. Dolan RD, Daly LE, Simmons CP, Ryan AM, Sim WM, Fallon M, et al. The Relationship between ECOG-PS, mGPS, BMI/WL Grade and Body Composition and Physical Function in Patients with Advanced Cancer. Cancers (Basel). 2020;12(5).
138. Shaver AL, Noyes K, Ochs-Balcom HM, Wilding G, Ray AD, Ma SJ, et al. A Retrospective Cohort Study of Myosteatosis and Quality of Life in Head and Neck Cancer Patients. Cancers (Basel). 2021;13(17).
139. Ge HP, Song DF, Wu P, Xu HF. Impact of sarcopenia and low muscle attenuation on outcomes of ovarian cancer: a systematic review and meta-analysis. Eur Rev Med Pharmacol Sci. 2023;27(10):4544-62.
140. Shachar SS, Williams GR, Muss HB, Nishijima TF. Prognostic value of sarcopenia in adults with solid tumours: A meta-analysis and systematic review. Eur J Cancer. 2016;57:58-67.
141. Aleixo GFP, Shachar SS, Nyrop KA, Muss HB, Malpica L, Williams GR. Myosteatosis and prognosis in cancer: Systematic review and meta-analysis. Crit Rev Oncol Hematol. 2020;145:102839.
142. Yang YW, Ming Y, Zhou YW, Xia X, Jia SL, Zhao YL, et al. Prognostic value of temporal muscle thickness, a novel radiographic marker of sarcopenia, in patients with brain tumor: A systematic review and meta-analysis. Nutrition. 2023;112:112077.
143. Gurney H. How to calculate the dose of chemotherapy. Br J Cancer. 2002;86(8):1297-302.
144. Griggs JJ, Bohlke K, Balaban EP, Dignam JJ, Hall ET, Harvey RD, et al. Appropriate Systemic Therapy Dosing for Obese Adult Patients With Cancer: ASCO Guideline Update. J Clin Oncol. 2021;39(18):2037-48.
145. Ansaripour A, Arjomandi Rad A, Koulouroudias M, Angouras D, Athanasiou T, Kourliouros A. Sarcopenia Adversely Affects Outcomes following Cardiac Surgery: A Systematic Review and Meta-Analysis. J Clin Med. 2023;12(17).
146. Park B, Bhat S, Xia W, Barazanchi AWH, Frampton C, Hill AG, et al. Consensus-defined sarcopenia predicts adverse outcomes after elective abdominal surgery: meta-analysis. BJS Open. 2023;7(4).
147. Weerink LBM, van der Hoorn A, van Leeuwen BL, de Bock GH. Low skeletal muscle mass and postoperative morbidity in surgical oncology: a systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2020;11(3):636-49.
148. Park A, Orlandini MF, Szor DJ, Junior UR, Tustumi F. The impact of sarcopenia on esophagectomy for cancer: a systematic review and meta-analysis. BMC Surg. 2023;23(1):240.
149. Sahin MEH, Akbas F, Yardimci AH, Sahin E. The effect of sarcopenia and sarcopenic obesity on survival in gastric cancer. BMC Cancer. 2023;23(1):911.
150. Kawaguchi Y, Hanaoka J, Ohshio Y, Okamoto K, Kaku R, Hayashi K, et al. Does sarcopenia affect postoperative short- and long-term outcomes in patients with lung cancer?—a systematic review and meta-analysis. Journal of Thoracic Disease. 2021;13(3):1358-69.
151. Li S, Wang T, Tong G, Li X, You D, Cong M. Prognostic Impact of Sarcopenia on Clinical Outcomes in Malignancies Treated With Immune Checkpoint Inhibitors: A Systematic Review and Meta-Analysis. Front Oncol. 2021;11:726257.
152. Beaudart C, Demonceau C, Reginster JY, Locquet M, Cesari M, Cruz Jentoft AJ, et al. Sarcopenia and health-related quality of life: A systematic review and meta-analysis. J Cachexia Sarcopenia Muscle. 2023;14(3):1228-43.
153. Hamaker M, Lund C, Te Molder M, Soubeyran P, Wildiers H, van Huis L, et al. Geriatric assessment in the management of older patients with cancer - A systematic review (update). J Geriatr Oncol. 2022;13(6):761-77.
154. Bernabei R, Landi F, Calvani R, Cesari M, Del Signore S, Anker SD, et al. Multicomponent intervention to prevent mobility disability in frail older adults: randomised controlled trial (SPRINTT project). BMJ. 2022;377:e068788.
155. Van Moll CC, Schep G, Vreugdenhil A, Savelberg HH, Husson O. The effect of training during treatment with chemotherapy on muscle strength and endurance capacity: A systematic review. Acta Oncol. 2016;55(5):539-46.
156. Bozzetti F. Chemotherapy-Induced Sarcopenia. Curr Treat Options Oncol. 2020;21(1):7.
157. Huang Q, Wu M, Wu X, Zhang Y, Xia Y. Muscle-to-tumor crosstalk: The effect of exercise-induced myokine on cancer progression. Biochim Biophys Acta Rev Cancer. 2022;1877(5):188761.
158. Cruz-Jentoft AJ, Gonzalez MC, Prado CM. Sarcopenia not equal low muscle mass. Eur Geriatr Med. 2023;14(2):225-8.
159. Meza-Valderrama D, Marco E, Davalos-Yerovi V, Muns MD, Tejero-Sanchez M, Duarte E, et al. Sarcopenia, Malnutrition, and

Cachexia: Adapting Definitions and Terminology of Nutritional Disorders in Older People with Cancer. Nutrients. 2021;13(3).
160. Chu MP, Lieffers J, Ghosh S, Belch A, Chua NS, Fontaine A, et al. Skeletal muscle density is an independent predictor of diffuse large B-cell lymphoma outcomes treated with rituximab-based chemoimmunotherapy. J Cachexia Sarcopenia Muscle. 2017;8(2):298-304.
161. Cortellini A, Bozzetti F, Palumbo P, Brocco D, Di Marino P, Tinari N, et al. Weighing the role of skeletal muscle mass and muscle density in cancer patients receiving PD-1/PD-L1 checkpoint inhibitors: a multicenter real-life study. Scientific Reports. 2020;10(1).
162. Ganju RG, TenNapel M, Spoozak L, Chen AM, Hoover A. The impact of skeletal muscle abnormalities on tolerance to adjuvant chemotherapy and radiation and outcome in patients with endometrial cancer. Journal of Medical Imaging and Radiation Oncology. 2020;64(1):104-12.
163. Youn S, Reif R, Chu MP, Smylie M, Walker J, Eurich DT, et al. Myosteatosis is prognostic in metastatic melanoma treated with nivolumab. Clinical Nutrition ESPEN. 2021;42:348-53.
164. Young AC, Quach HT, Song H, Davis EJ, Moslehi JJ, Ye F, et al. Impact of body composition on outcomes from anti-PD1 +/-anti-CTLA-4 treatment in melanoma. Journal for ImmunoTherapy of Cancer. 2020;8(2).
165. Aleixo GFP, Yu H, Chen YT, Nyrop KA, Louie RJ, Deal AM, et al. Myosteatosis evaluation using erector spinae and psoas muscles to predict adverse events during adjuvant chemotherapy for breast cancer. Breast Cancer Research and Treatment. 2021;186(2):487-95.