Aging Clinical and Experimental Research (2025) 37:162
https://doi.org/10.1007/s40520-025-03071-y

SYSTEMATIC REVIEW

The bidirectional association of malnutrition with depression and anxiety in patients with cancer: a systematic review and meta-analysis of evidence

Agnieszka Micek[1] · Ewa Błaszczyk-Bębenek[2] · Aneta Cebula[3] · Justyna Godos[4] · Kamil Konopka[5] · Anna Wąż[6] · Giuseppe Grosso[4]

Received: 14 April 2025 / Accepted: 8 May 2025

Abstract

Background Anxiety and depression are common mental health problems in cancer patients. At the same time, cancer patients often suffer from disease-related catabolic dysregulation and malnutrition. Emerging evidence has suggested the potential link between mental disorders and nutritional status.

Aims This study summarised the evidence for the association of malnutrition with anxiety and depression in cancer patients.

Methods A systematic search of PubMed and EMBASE databases was performed for observational studies published up to December 2024.

Results Forty-one articles were found eligible for inclusion in the systematic review, and twenty-nine in the meta-analysis. Compared with the normally nourished cancer patients, malnourished patients had a more than threefold (relative risk (RR) = 3.23, 95% CI 2.39, 4.38) and nearly twofold (RR = 1.87, 95% CI 1.48, 2.37) increased risk of depression and anxiety, respectively. Considering the studies that identified lower emotional status as a cause rather than an effect of malnutrition, the inverse association was confirmed only for depression (RR = 2.01, 95% CI 1.62, 2.49), but not for anxiety (RR = 1.38, 95% CI 0.68, 2.80). Finally, the standardised mean differences of the psychological scores showed significantly higher values in individuals with nutritional impairment compared to those with normal nutritional status (SMD = 0.69, 95% CI 0.50, 0.88 for depression and SMD = 0.54, 95% CI 0.26, 0.82 for anxiety).

Conclusions Mental health problems such as anxiety and depression are associated with malnutrition in cancer patients.

Keywords Nutritional status · Malnutrition · Cancer patients · Depression · Anxiety · Emotional distress

Introduction

Malnutrition is a pathological condition arising from inadequate nutrient intake, absorption, or utilization, resulting in altered body composition, specifically a reduction in fat-free mass, that leads to compromised physiological and cognitive functions and negatively impacts clinical prognosis in disease states [1]. Malnutrition is a major healthcare challenge, with a prevalence of 20–50% among hospitalised patients, and is common in those suffering from gastrointestinal, neurological and cancer diseases [2]. This devastating condition affects 15–40% of oncology patients at the time of diagnosis and rises to 40–80% with the introduction of anticancer treatment, with variations depending on the anatomical site and stage of the tumour, as well as demographic and social factors [3, 4]. Specifically, a high prevalence of malnutrition is observed in patients

✉ Agnieszka Micek
agnieszka.micek@uj.edu.pl

1 Statistical Laboratory, Faculty of Health Sciences, Jagiellonian University Medical College, 31-501 Cracow, Poland

2 Department of Nutrition and Drug Research, Faculty of Health Sciences, Jagiellonian University Medical College, 31-066 Cracow, Poland

3 Doctoral School of Medical and Health Sciences, Jagiellonian University Medical College, 31-121 Kraków, Poland

4 Department of Biomedical and Biotechnological Sciences, University of Catania, Catania, Italy

5 Department of Oncology, Jagiellonian University Medical College, 31-007 Cracow, Poland

6 Clinical Nutrition Team, University Hospital in Cracow, 30-688 Cracow, Poland

Published online: 23 May 2025

with upper gastrointestinal (40.2–49.5%), head and neck (28.6–67%), and lung (26.6–42.9%) cancers, as well as in patients with pancreatic, haematological, genitourinary, and bladder/uterine cancers [3]. Nutritional deficiencies may contribute to impaired response to chemotherapy, increased toxicity due to impaired pharmacokinetics and pharmacodynamics of chemotherapeutic drugs, and aggravation of complications, which may ultimately lead to 20% of deaths in cancer patients [5, 6]. In addition, the effects of cancer-related malnutrition include fatigue, higher risk of infection and compromised immune competence, exacerbated by impaired immunity due to, among other things, cytotoxic agents [7].

Cancer patients have been reported to further suffer from psychological conditions, such as emotional distress [8]. Cancer is perceived as a serious and life-threatening condition, with the whole course of the disease (from diagnosis to treatment) potentially becoming a chronic stressor for the psyche [8]. Depression affects up to a third of cancer patients, with the highest rates being reported in patients with colon (32.4%), haematological (29.5%) and brain tumours (25.5%) [9]. The prevalence of anxiety in cancer patients is also high, averaging about 10%, although there is a wide variation between studies [10]. Oncology patients in urgent need of psychological and psychiatric support are rarely identified by clinicians and referred to specialists in these areas [11]. However, depression and anxiety, as well as malnutrition, reduce quality of life, negatively affect compliance with medical recommendations, and contribute to higher mortality in the cancer patient population [12].

While some studies suggest that cancer-related malnutrition and psychiatric disorders are closely linked, there is scarce literature on this topic, especially in terms of quantitative evidence summarisation. Therefore, the aim of this meta-analysis is to investigate the bidirectional association of anxiety and depression with malnutrition in cancer patients. A better understanding of this relationship could contribute to an earlier diagnosis of each condition and thus improve the management of the underlying disease.

Methods

For a more standardized reporting including background, search strategy, methods, results, discussion, and conclusion we followed Meta-analyses Of Observational Studies in Epidemiology (MOOSE) guideline and completed checklist (Supplementary Table 1). The systematic review protocol was registered in the International Prospective Register of Systematic Reviews database (PROSPERO, ID: CRD42024515685, at https://www.crd.york.ac.uk/prospero/).

Search strategy and study selection

Potentially eligible studies were identified through a systematic search of MEDLINE (via PubMed) and EMBASE databases from their inception up to the end of 2023. The search strategy referred to the specific keywords and subject headings combined by Boolean commands and related to nutritional status, and psychological outcomes such as anxiety, depression and distress. We applied filters for human studies and English, Polish or Italian language. In addition, the EMBASE search was restricted to articles or press articles or editorials. The specific descriptors (EMTREE terms from EMBASE and MeSH from PubMed) were used to adapt the strategy to the requirements of each database. Details are presented in Supplementary Table 2. The quest was repeated before the final analysis, extending the search period to December 2024. Finally, a manual scrutiny of the reference lists of all identified articles was performed to search for further information that may not have been identified. The PICOS framework was employed to structure the eligibility criteria (Supplementary Table 3). To be included in a systematic review, a study had to meet the following requirements: (i) adult cancer population examined; (ii) observational design (cohort, cross-sectional, or case–control study); (iii) reported association between nutritional status and depression or anxiety; and additionally for being included in a meta-analysis the study had to (iv) provide an appropriate measure of effect for the association investigated. If more than one article reported results on the same cohort, only the study with the larger cohort size, the longest follow-up, or the most comprehensive data was included in the meta-analysis. If an article reported the results for two different cancer subpopulations (e.g. for digestive and non-digestive tumours), they were treated as separate studies. The systematic literature search and study selection were performed by two independent researchers and any disagreements were resolved with the possible assistance of another investigator.

Data extraction and quality assessment

A standardised electronic form was applied to collect data from relevant studies. We extracted the key information from the articles such as: author name, year of publication, study setting and design, details of the cancer population examined, including distribution of cancer anatomical sites and stages, sample size by sex, age of participants, psychological outcome of interest (depression, anxiety), tools used to assess psychological and nutritional status, main findings of the research, measures of association

from the most adjusted model including 95% confidence intervals. The methodological quality of the studies in the three domains of selection, comparability and results was assessed using the Newcastle–Ottawa Quality Assessment Scale [13] by two investigators independently and any incongruity was discussed and resolved through a consensus. High quality was defined as obtaining at least 5 points for cross-sectional and at least 7 points for case–control and prospective studies.

Statistical analysis

The identified articles presented different measures of the association between nutritional status (NS) and psychological status (PS): (i) odds ratio (OR) and relative risk (OR was treated as approximately equivalent to relative risk and both were further referred to as RR), reflecting the effect of NS on PS, or vice versa the effect of PS on NS, for both NS, and PS expressed as categorical variables; (ii) mean (M) with standard deviation (SD) of depression, or anxiety scores across different nutritional status groups or equivalent parameters allowing for their calculation under the assumption of normality of the distribution (e.g. 95% confidence interval (CI), median (Me) with range (R), or interquartile range (Q1-Q3)), and finally (iii) correlation and/or linear regression coefficients. For categorical NS and PS two separate meta-analyses were performed: the first one to compare the risk of depression or anxiety between extreme categories of nutritional status, or alternatively the second one to compare the risk of malnutrition between extreme categories of psychological status (in the literature possible bidirectional relationship was postulated, in our meta-analysis the direction of the association was determined by the design of the study in the original article). The logarithms of the RRs from the most adjusted models were pooled, but in some cases only the crude RR could be calculated based on an extracted cross-tabulation of the joint distribution of NS and PS. Because of the variety of instruments used to assess NS and PS, it wasn't possible to do a quantitative synthesis of correlations and/or linear regression coefficients, so these results were only summarised in the systematic review. At the same time, standard mean differences were calculated comparing depression or anxiety scores between extreme categories of nutritional status, and then harmonised across studies.

To account for between-study variability in all quantitative syntheses, effect sizes were harmonised using the Der Simonian and Laird random effects model, with study weights calculated as the inverse of the sum of the between-study and within-study variance. The Q test under the level of significance defined at 0.10 was engaged to assess heterogeneity and was complemented by I^2 statistic. I^2 ranges $<25\%$, 25–50%, 50–75%, and $>75\%$ were suggestive of no, low, moderate, and significant heterogeneity, respectively. The potential publication bias and/or small-study effect was evaluated visually by verifying asymmetry in funnel plots and quantitatively by Egger's regression test. Next, to examine the sensitivity of the results to publication bias, a trim-and-fill method for estimating and adjusting for the number and outcomes of missing studies was applied. The effect of omitting one study at a time on pooled estimates was verified in the influential analysis. Subgroup analyses were undertaken by tumour anatomical site, cancer stage, method of assessment of nutritional and psychological status, and study quality. All analyses were based on two-tailed tests and were conducted with R version 4.4.1 (Development Core Team). Statistical significance was defined as $P < 0.05$ (except for the Q test assessing heterogeneity).

Results

Study characteristics

A total of 3495 studies (2007 identified from PubMed and 1488 from Embase) were considered to be of potential interest for this systematic search. After removing 858 duplicates and excluding 2342 studies at both the title and abstract screening stages, 295 articles were eligible for full-text evaluation. An initial screening was performed based on the following reasons: lack of information on nutritional ($n = 76$) or psychological status ($n = 68$), no association between exposure and outcome of interest ($n = 42$), different study population or study design ($n = 62$), and article type, e.g. correspondence to previously published article ($n = 3$). The resulting 43 studies were further examined for overlaps and additional reasons for potential exclusions. After the final removal of 1 study that did not assess depression or anxiety but distress and 2 intervention trials, a total of 41 observational studies were included in this systematic review [11, 14–53], of which 29 were included in the meta-analysis [25–53] (Supplementary Fig. 1).

The background characteristics of the studies included in the systematic review, and a summary of the main findings are reported in Table 1. A total of 7 were prospective studies, 30 had a cross-sectional design and 4 were case–control studies. Fourteen trials were conducted in European countries, 12 in Western countries, with 4 specifically involving Southern and 8 Northern American cohorts, while 15 included Eastern Asian countries. Most studies ($n = 18$) involved cancer patients regardless of the anatomical site of the tumour, 6 examined head and neck cancer population, 9 digestive, 4 lung, and 4 sex-related cancers (prostate, breast, gynecological). A total of 21 studies explored the relation between nutritional status and depression only, and 20 accounted for both depression and anxiety. A variety of

Table 1 Characteristics of the studies included in systematic review and meta-analysis

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Studies included in both systematic review and meta-analysis										
Bruera et al. (1984), Argentina, [25]	BRCA (36%), LUNG (12.5%), STAD (11%), COAD (10%), OV (10%), OTH (20.5%)	Advanced cancer	Advanced solid tumor patients receiving chemotherapy (all had at least three courses before being admitted to the study) and treated on an outpatient basis	D; CS; 57	M: 53, SD: 12	NN: > 90%, AMN 80–90% (moderately), MN: < 80% (severely) based on AVPSD (averaged percentage of the standard value for 5 tests: TSF, AMC, ALB, CREAT, HI, WI)	NN: 53%, MN: 47% (moderately 21% or severe 26%)	ND: ≤ 5, BD: 6–20 (No or mild to moderate), D: > 20 (severe) based on HAMD	ND: 69% (No or mild to moderate), D: 31% (severe)	Hamilton's test was positive in 24 of 27 patients with normal nutritional status and 24 of 30 malnourished patients. The malnourished group showed a significantly higher incidence of severe depression (16 of 27 patients [59%] vs six of 30 [20%]; P = 0.026). No significant difference was found between the normal and malnourished patients in reference to tumor burden
Westin et al. (1988), Sweden, [26]	HNSC	All stages	A variety of adult patients with HNSC in different stages of disease and treatment	D; CS; 45/8	M: 64, R: 29–90	MN: two or more conditions: WL ≥ 10%, low AMC, low TSF, WI < 0.80, ALB < 33, K depletion	NN: 73%, MN: 27%	D: SPSI > 1.5, Probable D: CPPRS11 ≥ 9	ND: 74%, BD: 17%, D: 9%,	All 5 cancer patients who were classified as depressed had cachexia. Another 37 cancer patients without weight loss as well as 11 patients with weight loss, didn't have signs of mental depression. 18 cases of mental depression was significantly overrepresented among the patients with malnutrition (P < .01)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Daudt et al. (2012), Canada, [27]	COADREAD	All (in situ disease and all histologies)	New colorectal cancer patients diagnosed and referred to the cancer clinic. Exclusions: Sarcoma, lymphoma, and melanoma	AnX, D; CS; 142/110	M: 67.3, SD: 11.0	NN: <4, MN: ≥4 based on PG-SGA score	NN: 29%, MN: 71%	ND: <11, D: ≥11 based on PSSCAN; NAnX: <11, AnX: ≥11 based on PSSCAN	ND: 93%, D: 7%, NAnX: 90%, AnX: 10%	After stepwise AIC model selection, an ordinal logistic regression model containing the variables depression, anxiety, gender, health coverage, and marital status was found to best explain the nutritional score. Depressed and anxious patients respectively had 5.6 and 2.2 times greater the odds of being in a higher nutritional risk category than non depressed and not anxious patients
Nho et al. (2014), Republic of Korea, [28]	GC	I (38.8%), II (16.3%), III (31.0%), IV (14%)	Gynecologic cancer patients aged over 20 years, without other major health problems that could potentially influence nutritional status. Exclusions: Uncontrolled diabetes mellitus, infection and inflammation, liver failure, renal failure	D; CS; 0/129	M: 52.9, SD: 11.7, IC: 20 +	NN: <9, MN: ≥9 based on PG-SGA score	NN: 47%, MN: 53%	ND: <16, D: ≥16 based on BDI	ND: 74%, D: 26%,	Depression (OR = 1.087, 95% CI = 1.020–1.158, P = 0.010) and appetite were significant factors predicting malnutrition in patients with gynecologic cancer

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Paillaud et al. (2014), France, [29]	BRCA (20.8%), UTC (13.7%), PRAD (10.0%), COADREAD (27.8%), UGIC or LIHC (20.0%), OTH (7.7%)	Various stages (from localised to metastatic)	Solid cancer patients aged 70 years or older at referral to two geriatric oncology clinics between 2007 and 2010 who initiated cancer treatment (chemotherapy, radiotherapy, surgery, and/or hormonal therapy). Exclusions: Haematologic malignancies	D; CS; 213/229	M: 80.0, SD: 5.8, IC: 70 +	NN: ≥ 23.5, AMN: 17–23.5, MN: < 17 based on MNA score	NN: 36%, AMN: 44%, MN: 21%	ND: < 1, D: ≥ 1 based on MiniGDS	ND: 67%, D: 33%,	In a multivariate multinomial logistic model adjusted to metastasis, fall risk (only in digestive cancer analysis) and cognitive impairment, depressed mood (Mini-GDS ≥ 1) was associated with being in risk for malnutrition (OR, 95% CI 1.49, 0.66–3.38 in digestive cancer patients and 3.13, 1.51–6.50 in non-digestive cancer patients) as well as with being malnourished (OR, 95% CI 3.25, 0.29–8.15 in digestive cancer patients and 11.11, 3.23–37.17 in non-digestive cancer patients)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Hong et al. (2016), China, [30]	NPC	I (5.77%), II (19.23%), III (39.42%), and IV (35.58%)	NPC patients diagnosed and treated at the First Affiliated Hospital of Fujian Medical University. Inclusions: 1) aged 18 years old to 70 years old; 2) an Eastern Cooperative Oncology Group performance status score of < 2; and 3) had no history of mental or psychological disease. Exclusions: Patients with a history of malnutrition or had any form of inflammation before diagnosis	D, AnX; P; 77/27	M: 49.5, SD: 11.0, IC: 18–70	NN: if all 9 NI normal, AMN:. if 1–4 NI abnormal; MN: if ≥ 5 NI abnormal; based on 9 NI such as BMI, UAC, TSF, HB, ALB, PA, TRF, RBC, and TLC	NN: (29.8%), AMN: (70.2%), MN: (0%) before radiotherapy; NN: (0.0%), AMN: (69.2%), MN: (30.8%) after radiotherapy;	ND: ≤ 11, D: > 11 based on HADS-D, NAnX: ≤ 11, AnX: > 11 based on HADS-A	ND: 85.6%, D: 14.4%; NAnX: 93.3%, AnX: 6.7%	Multivariate logistic regression showed that the risk factors for poor nutritional status after radiotherapy were depression (β = 0.043, SE = 0.019, P = 0.024) but not anxiety, as well as old age (β = 0.042, SE = 0.06, P = 0.489), female gender (P < 0.001), high side effect score (P = 0.007), late stages of the disease (P = 0.013), and moderate nutritional status before radiotherapy (P D 0.015)
Tan et al. (2016), Singapore, [31]	GIC (67.1%), LUNG (11.6%), GUC (4.8%), OTH (16.5%)	I-II (15.3%), III-IV (84.7%)	Patients aged 70 years and older with a diagnosis of cancer at any stage	D; CS; 153/96	Me: 77, R: 70–94, IC: 70 +	NN: 0–2, AMN: 3–5,MN: ≥ 6 based on NSI checklist score	NN: 26%, MN: 74%	ND: ≤ 5, D: > 5 based on GDS	ND: 72%, D: 28%,	Multivariate logistic regression analysis identified presence of depression (OR 5.99; 95% CI, 1.99–18.02) as significant independent factors associated with moderate to high nutritional risk after adjustment to stage of disease, ECOG performance status and haemoglobin levels)
Chabowski et al. (2018), Poland, [35]	LUNG	T1 (19%), T2 (34%), T3 (11%), T4 (35%)	Hospitalised lung cancer patients	AnX, D; CS; 142/115	M: 63.2, SD: 9.37, IQR: 59–68	NN: ≥ 23.5, AMN: 17–23.5, MN: < 17 based on MNA score	NN: 44%, AMN: 33%, MN: 23%	ND: < 8, BD: 8–10, D: ≥ 11 based on HADS-D; NAnX: < 8, BAnX: 8–10, AnX: ≥ 11 based on HADS-A;	ND: 35%, BD: 25%, D: 40%,	Spearman's rank correlation analysis revealed a negative correlation between nutritional status and anxiety (r = −0.68, P < 0.001), and nutritional status and depression (r = −0.60, P < 0.001)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Zhang et al. (2019), United States, [32]	HC (31.6%), SOLID (68.4%): PRAD, BRCA, COADREAD, BLCA, LUNG	Local (50.9%) metastasis (17.6%), NA (31.5%)	Patients 65 years of age and older with hematologic malignancies or solid tumors undergoing cancer care who were referred for comprehensive geriatric assessment at the Program for Healthy Aging (comorbid diagnoses included dementia, mild cognitive impairment, frailty, and functional impairment). Exclusions: no cancer treatment	D; CS; 225/229	Me: 78, R: 65–96, IC: 65 +	NN: 12–14, AMN: 8–11, MN: 0–7 based on MNA score	NN: 58%, MN: 42%	ND: ≤ 10, D: > 10 based on PHQ-9	ND: 72%, D: 28%,	In multivariable logistic regression analysis, after controlling for potential confounders (social support, frailty, gait speed, function of status, cognitive diagnosis, low physical activity, ECOG performance status), patients who had malnutrition were 2.53-times more likely to have major depression (OR = 2.53, 95% CI 1.23–5.24, p = 0.01) and 3.82 times more likely to have frailty (OR = 3.82, 95% CI 1.35–10.84, p = 0.01) than those without malnutrition

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Gosak et al. (2020), Slovenia, [33]	HNSC (Oral cavity 7 (17.5%), Oropharynx 21 (52.5%), Hypopharynx 7 (17.5%), Larynx 5 (12.5%))	III (17.5%), IVA (67.5%), IV B (15%)	Adult men with histologically confirmed squamous cell carcinoma of the oral cavity, oropharynx, hypopharynx, or larynx, treated with definitive or postoperative (chemo) radiotherapy (RT). Exclusions: patients with simultaneously diagnosed or previously treated malignancy, a pacemaker or defibrillator, severe chronic diseases, active uncontrolled infection, neuromuscular disorders, hemiplegia and arthritis affecting the hands, patients considered not being able to understand and complete the questionnaires	D, AnX; P; 40/0	M: 62.5, SD: 7.6, IC: 18 +	NN: < 3, MN: ≥ 3 based on NRS-2002	NN: 72.5%, MN: 20%, CaX: 7.5% at baseline; NN: 65%, MN: 10%, CaX: 25% at 3 months post therapy;	ND: ≤ 7, D: > 7 based on HADS-D, NAnX: ≤ 7, AnX: > 7 based on HADS-A	ND: 92.5%, D: 7.5% at baseline; ND: 85%, D: 15% 3 months post therapy; NAnX: 72.5%, AnX: 27.5% at baseline; NAnX: 90%, AnX: 10% 3 months post therapy	At assessments 1 and 2, the majority of patients without psychological distress revealed by HADS-A were well nourished, whereas distress was more often recorded among malnourished/cachectic patients ($p = 0.017$ and $p = 0.020$). According to the HADS-D, significantly more malnourished/cachectic patients than well-nourished ones were found distressed at assessments 2 and 3 ($p = 0.045$ and $p = 0.023$)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Sun et al. (2020), China, [34]	LUNG (29.1%), DC (47.4%), HNSC, LYM, BRCA, GC, STT	I (1.8%), II (5.8%), III (27.0%), IV (65.5%)	Patients from cancer centres of four different hospitals in Wuhan, Hubei Province, older than 18 years, who could read and respond to questions or require minimal assistance from the family or an interpreter, and were diagnosed with cancer pathologically	AnX, D; CS; 312/216	M: 54.6, SD: 11.5, IC: 18 +	Cachexia: (i) WL > 5% or (ii) WL > 2% and ≤ 5% and with BMI < 20 or (iii) WL > 2% and ≤ 5% and with BMI ≥ 20 and SMI met the diagnostic criteria for sarcopenia	NCaX: 46%, CaX: 54%	ND: ≤ 10, D: > 10 based on PHQ-9; NAnX: < 10, Anx: ≥ 10 based on GAD-7	ND: 77%, D: 23%, NAnX: 85%, AnX: 15%	In comparison with the non-cachexia group, the cachexia group had higher PHQ-9 score, GAD-7 score, higher prevalence of depression, anxiety. Taking the basic characteristics (age, tumour stage, gender, marital status and so on), in multivariate linear regression analysis cachexia was associated with higher depression scores (unstandardised coefficient β = 2.123, 95% CI 1.066 to 3.180, p < 0.001) and anxiety scores (β = 1.123, 95% CI 0.148 to 2.097, p = 0.024)
Williams et al. (2020), United States, [37]	GIC (COAD-READ (33.6%), PAAD (24.4%), HPB (17.0%), OTH)	0-II (28.3%), III (26.5%), IV (45.2%)	Older (≥ age 60 years) patients that had a gastrointestinal malignancy, and had performed a geriatric assessment prior to any potentially planned chemotherapy. Exclusions: Length of stay below 48 h, readmission before 1 month, and a situation of actively dying	AnX, D; CS; 191/145	Me: 70.1, R: 60–96	NN: < 6, MN: ≥ 6 based on abPG-SGA score	NN: 48%, MN: 52%	ND: 0–3, D: ≥ 4 based on PROMIS-Cancer scales (Anxiety 9 items, Depression 10 items)	ND: 87%, D: 13%, NAnX: 82%, AnX: 18%	In multivariable logistic regression modelling controlling for age at study, sex, education level, marital status, employment, cancer type, and cancer stage, malnutrition was independently associated with both anxiety (OR, 95% CI 3.0, 1.5–6.1) and depression (OR, 95% CI 5.1, 2.0–12.8)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Ehrsson et al. (2021), Sweden, [38]	HNSC	I-II (58.6%), III-IV (40.7%), NA (0.7%)	Patients with untreated and curative intent HNSC with a performance status of 0–2 rendering from theWorld Health Organization (WHO). Exclusions: inability to understand the Swedish language, severe alcohol abuse, cognitive diagnoses such as senile dementia or mental disturbance, or malignant neoplasm previously treated within the past five years	AnX, D; P; 198/75	M: 63.0, SD: 11.0	At least one phenotypic criterion and one etiologic criterion of GLIM	NN: 55%, MN: 45%	ND: 0–6 (mild), BD: 7–10 (moderate), D: > 10 (severe) based on HADS-D; NAnX: 0–6 (mild), BAnX: 7–10 (moderate), AnX: > 10 (severe) based on HADS-A	ND: 75%, D: 25%, NAnX: 78%, AnX: 22%	Seven weeks after the start of treatment patients with malnutrition scored significantly worse in depression compared to patients with no malnutrition (Mean, SD: 4.51, 4.15 vs 3.40, 3.38, p = 0.047). No significant difference was seen between the two groups for anxiety (p = 0.290)
Gillis et al. (2021), Canada, [36]	COADREAD	I + II (70%), III + IV (30% AJCC classify.)	Adults scheduled for a primary colorectal resection of nonmetastatic, malignant disease. Exclusions: Inability to speak English or French, emergency surgery or elective surgery scheduled earlier than 4 weeks from recruitment date, and premorbid conditions that contraindicated exercise	AnX, D; CS; 154/112	M: 71, SD: 11, IC: 18 +	Need of intervention: 4–8, critical need of nutrition intervention: ≥ 9 based on PG-SGA score	NN: 39%, AMN: 17%, MN: 44%	No categorisation, D and AnX: based on HADS-D, HADS-A as continuous	NR	As nutritional status worsened, every component of the HADS were significantly worse, in consecutive categories of PG-SGA scores: < 4, 4–8, > 8 Me [Q1-Q3] were equal to: 5 [2–8], 6 [4–8], and 8 [3–10] for anxiety, and 2 [1–5], 3 [1–7] and 6 [3–10] for depression

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Sánchez-Torralvo et al. (2022), Spain, [39]	LUNG (25.2%), COAD (13.0%), BRCA (13%), EGJC (11.8%)	I (2.5%), II (4.6%), III (17.7%), IV (75.2%)	Patients with solid or hematological neoplasm after admission to the oncology ward, length of stay above 48 h. Exclusions: Patients with length of stay below 48 h, readmission before 1 month, and a situation of actively dying	AnX, D; CS; 157/125	M: 60.4, SD: 12.6	At least one phenotypic criterion and one etiologic criterion of GLIM	NN: 20%, MN: 80%	ND: 0–7, BD: 8–11, D: > 11 based on HADS-D; NAnX: 0–7, BAnX: 8–11, AnX: > 11 based on HADS-A	ND: 55%, BD: 18%, D: 27%, NAnX: 46%, BAnX: 20%, AnX: 26%	In malnourished patients, HADS score was non-significantly higher with respect to anxiety (Means ± SD: 8.5 ± 4.3 in malnourished vs 7.1 ± 4.6 in well-nourished; p = 0.06) and was significantly higher with respect to depression (Means ± SD: 8.2 ± 4.6 in malnourished vs 5.3 ± 4.0 in well-nourished; p < 0.001). After controlling for potential confounders (age, sex, and cancer stage), malnourished patients were 1.98 times more likely to present anxious symptomatology (95% CI 1.01–3.98; p = 0.049) and 6.29 times more likely to present depressive symptomatology (95% CI 1.73–20.47; p = 0.005)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Soria-Utrilla et al. (2022), Spain, [40]	COADREAD	I (13.0%), II (31.2%), III (44.2%), IV (11.6%)	Patients after medical evaluation at the Coloproctology Unit, aged ≥ 18 years old, diagnosed with colorectal cancer with a proposal for curative surgery	AnX, D; CS; 123/92	M: 68.4, SD: 10.3, IC: 18 +	At least one phenotypic criterion and one etiologic criterion of GLIM	NN: 46%, MN: 54%	ND: 0–7, BD: 8–11, D: > 11 based on HADS-D; NAnX: 0–7, BAnX: 8–11, AnX: > 11 based on HADS-A	ND: 78%, BD: 14%, D: 8%, NAnX: 58%, BAnX: 16%, AnX: 26%	The HADS score for depression subscale was significantly higher in malnourished patients than in well-nourished (Means ± SD: 5.61 ± 3.65 vs. 3.95 ± 2.68; p = 0.001), and was not significantly higher with respect to anxiety (Means ± SD: 7.57 ± 4.96 in malnourished vs. 6.62 ± 3.94 in well-nourished; p = 0.15). After controlling for potential confounders (age, sex, and cancer stage), malnourished patients were 10.19 times more likely to present probable depression (95% CI 1.13–92.24; p = 0.039). and 2.19 times more likely to present probable anxiety (95% CI 1.04–4.63; p = 0.04)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Xiao et al. (2022), China, [41]	STAD	I (16.0%), II (18.9%), III (53.8%), IV (11.3%)	Patients, aged more than 18 years, with gastric cancer who underwent gastric cancer-related surgery for the first time from 2014 to 2019 in Shaanxi Provincial People's Hospital. Exclusions: Patients with incomplete data and those who could not be followed up	D; P; 84/22	Me: 67, R: 43–85	NN: < 5, MN: ≥ 5 based on CONUT score	NN: 40.6%, MN: 59.4%	ND: < 36, D: ≥ 36 based on S-AI (subscale of STAI)	Mean ± SD for S-AI: 35.6 ± 3.02 in NN group, 37.13 ± 4.16 in MN group	The CONUT score was correlated with the state anxiety questionnaire (S-AI) for evaluating psychological status (Means ± SD: 35.6 ± 3.02 in CONUT score < 5 group vs 37.13 ± 4.16 in CONUT score ≥ 5 group, P = 0.032). However, further multiple logistic regression analysis exhibited that the CONUT score was not an independent risk factor for psychological status (OR, 95% CI 0.76, 0.35–1.66, p = 0.485 for CONUT, low versus high)
Xue et al. (2022), China, [53]	LUNG (100%)	III (%), IV (76.9%)	Hospitalized patients receiving systematic treatment. Exclusions: comorbidity with other malignancies; poor vision and hearing and inability to answer questions; severe psychiatric illness; and patients with expected survival less than 3 months or who are in hospice care	D; CS; 36/68	M: NR, SD: NR, IC: 18 +	NN: < 4, MN: ≥ 4 based on PG-SGA score	NN: 31.7%, MN: 68.3%	ND: ≤ 7, D: ≥ 8 (possible or definite) based on HAMD	ND: 68.3%, D: 31.7%	Severe malnourished patients were tendency to slightly elevated risk of depression compared with well-nourished (OR = 1.72, 95% CI 0.49–6.06), however subjects with sarcopenia have more than four times the risk of suffering from depression than patients without it (OR = 4.13, 95% CI = 1.39—12.29)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Yildirim et al. (2022), Turkey, [42]	LUNG (36.7%), BRCA (18%), GUC (13.1%)	III (56.3%), IV (43.7%)	Cancer patients receiving treatment at the internal medicine and oncology services of a university hospital, 18 years or older, volunteers having the capacity to understand and interpret the questions, and having a diagnosis of stage III or IV cancer	D; CS; 126/119	M: 60.3, SD: 14.9, IC: 18 +, R 20–90	NN: < 3, MN: ≥ 3 based on NRS-2002 score	NN: 61%, MN: 39%	ND: < 10, D: ≥ 10 based on BDI	ND: 4%, BD: 5%, D: 91%,	Correlation analysis showed a positive and significant relationship between the NRS-2002 scores and the Beck Depression Inventory scores ($r = 0.409$; $p < 0.001$). On the other hand, there was no significant difference in the mean Beck Depression Inventory scores of the patients based on their nutrition status ($p > 0.05$)
Evangelou et al. (2023), Greek, [43]	BREAST (13.1%), LUNG (16.1%), GIC and COADREAD (27.0%), HNSC and spinal (29.2%), OTH (14.6%)	I, II, III, IV (% NR)	Patients hospitalized or followed cancer treatment with all types and stages of cancer. Exclusions: Patients' age < 18 years; bedridden patients in advanced stage of the disease who were unable to carry out the measurements; patients facing difficulties in communication	AnX, D; CS; 74/78	M: 61.0, SD: 14.0, IC: 18 +,	NN: "Good nutritional status", AMN: "moderately malnourished", MN: "severely malnourished" based on PG-SGA score	NN: 25%, AMN: 20%, MN: 55%	ND: < 6, D: ≥ 6 based on BEDS; ND: 0–6, BD: 7–10, D: > 10 based on HADS-D; NAnX: 0–6, BAnX: 7–10, AnX: > 10 based on HADS-A	ND: 38%, BD: 30%, D: 32%, NAnX: 49%, BAnX: 28%, AnX: 23%	In ordinal logistic regression after controlling for age, gender, cancer type categories, as nutritional status worsened and BMI depression and anxiety based on HADS tended more toward abnormal (OR = 1.52, P = 0.072, and OR = 1.89, P = 0.009, respectively), for all three models. The same relationship, between nutritional status and depression, was observed based on BEDS (OR = 2.27, P = 0.002)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Luo et al. (2023), China, [44]	ESCA	< II (57.2%), ≥ II (42.8%)	Patients with esophageal cancer (diagnosed by cytology or pathology), inpatients with primary esophageal cancer; with Karnofsky (kPS) score > 70 during the peri-radiotherapy who received treatment. Exclusions: Combination of mania and other psychiatric diseases; malignant tumors; acute and chronic infectious diseases; lactating or pregnant women; presence of serious organ diseases; serious mental disorders; loss of the ability to communicate	AnX, D; CS; 176/163	M: NR, SD: NR, 42.8% 60-, 57.2% 60 +	NN: < 9, MN: ≥ 9 based on PG-SGA score	Mean ± SD: 1.95 ± 1.66 in group with negative emotions, 1.68 ± 1.94 in group without negative emotions	ND: ≤ 53, D: > 53 based on SDS; NAnX: ≤ 50, AnX: > 50 based on SAS	NoNegEmot: 82%, NegEmot: 18%,	Multiple logistic regression analysis after adjustment for advanced age, tumor diameter, concomitant gastrointestinal symptoms, radiation dose, dysphagia, concomitant radiation esophagitis, hemoglobin and albumin concentration found that negative emotions (OR = 2.547, P = 0.038) were a risk factor for malnutrition in patients with esophageal cancer
Nucci et al. (2023), Italy, [45]	COADREAD (24.4%), soft tissue (16.7%), NHL (14.4%), PAAD and CHOL (11.1%), STAD (7.8%), BM (6.7%)	I (10.0%), II (11.1%), III (12.2%), IV (66.7%)	Patients admitted to the hospital, at least 18 years old, able to complete the questionnaire administered upon hospital admission. Exclusions: patients with diagnosis of cancer upon the admission day	AnX, D; CS; 57/33	M: 56.7, SD: 15.1, IC: 18 +	NN: < 3, MN: ≥ 3 based on NRS-2002 score	NN: 66%, MN: 34%	ND: < 8, D: ≥ 8 based on HADS-D; NAnX: < 8, AnX: ≥ 8 based on HADS-A	ND: 74%, BD: 18%, D: 8%, NAnX: 71%, BAnX: 17%, AnX: 12%	After controlling for age and sex every unit increase of NRS-2002 was associated with a 71% higher risk of depression (OR = 1.71, 95% CI 1.20–2.43 based on ordered logistic regression)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Sucuoglu Isleyen et al. (2023), Turkey, [46]	BRCA, GIC, thoracic, GC, PRAD, BLCA, SARC (% NR)	I-II-III (57.8%), IV (42.2%)	Patients aged 65 years and older with a cancer diagnosis who were admitted to one oncology outpatient clinic in Turkey. Exclusions: Patients with dementia or delirium, malnutrition, severe vision and hearing impairment, or had acute cerebrovascular event, sepsis, acute renal failure, and acute respiratory failure	D; CS; 90/90	M: 73.0, SD: 5.6, IC: 65 +	NN: ≥ 23.5, AMN: 17–23.5, MN: < 17 based on MNA score	NN: 71%, AMN: 29%,	ND: < 5, D: ≥ 5 based on GDS-15	ND: 71%, D: 29%,	After adjustment for age, sex, and body mass index; depression was associated with malnutrition risk compared to well-nourished patients (OR: 6.24; 95% CI, 2.75–14.18, $p < 0.05$)
Xiao et al. (2023), China, [47]	BRCA	II (55.4%), III (44.6%)	Women with clinically diagnosed breast cancer who underwent anthracycline and taxane-based NAC for their treatment and had a minimum age of 18 years. Exclusions: Other serious medical conditions, such as lung cancer, chronic kidney failure, and severe cardiovascular or cerebrovascular disease; a mental disability; and a major life event in the last three months	D; P; 0/121	M: 51.0, SD: 10.0, R: 31–80	NN: < 3, MN: ≥ 3 based on NRS-2002 score	NN: 80%, MN: 20%	ND ≤ 53, D: > 53 based on posttreatment SDS (and without pretreatment depressive symptoms)	ND: 61%, D: 39%,	Patients in the depressive group had higher nutritional risk than those in the pretreatment non-depressive group undergoing neoadjuvant chemotherapy. Based on the NRS-2002 scores, there were 14 individuals at nutritional risk (screening scores ≥ 3) in the depressive group after treatment, compared with 10 individuals in the non-depressive group ($p = 0.029$) And higher neutrophil-to-lymphocyte ratio ($p = 0.039$) and lower prognostic nutritional index level ($p = 0.0021$) were found in patients with pretreatment depressive status

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Kim et al. (2024), Republic of Korea, [48]	LIHC	0 (14.8%), A (37.0%), B (6.2%), C (39.5%), D (2.5%)	Liver cancer outpatients at a tertiary university hospital. Eligibility criteria: 1) age > 18 years; 2) diagnosis of primary liver cancer confirmed by an internal medicine specialist according to the ICD-10; and 3) absence of severe cognitive impairment. Exclusions: serious medical conditions that could affect nutritional status, except for liver cancer	D; CS; 130/32	M: 64.7, SD: 8.5, IC: 18 +	NN: <9, MN: ≥9 based on PG-SGA score	NN: 83%, MN: 17%	ND: 0–13, MildD: 14–19, ModD: 10–28 and SevD: 29–63 based on BDI-II	ND (72.2%), MildD (8.6%), ModD (13.0%), SevD (6.2%)	In the malnutrition group mean score of depression as well as frequency of occurrence of mild, moderate and severe depression was significantly higher than in the non-malnutrition group (t (160, 162) = −4.13, p < .001), and (χ^2 = 14.55, p = 0.002). Independently of physical symptom distress, stage of liver cancer and BMI, logistic regression analysis showed that depression was statistically significant predictor of malnutrition (OR = 1.07, 95% CI 1.01–1.13, p = 0.030 per 1 point of BDI-II)
McLay et al. (2024), Canada, [51]	BRCA (29.0%), GIC (20.3%), HC (19.3%), LUNG (12.3%), OTH (19.9%)	0 (2.4%), I (17%), II (15%), III (14%), IV (18%), (14%), Not staged (34%)	Consecutive oncology outpatients aged 18 and older referred to the Grand River Regional Cancer Centre who completed the malnutrition screening tool at first consult and who had a radiation or medical oncology consult	AnX, D; CS; 785/1286	M: 65.7, SD: 13.7, IC: 18 +	NN: <6, MN: ≥6 based on abPG-SGA score	NN: 34%, MN: 66%	ESAS-r	NR	Correlation analysis using Spearman's rho found that malnutrition risk (abPG-SGA score) was positively and significantly correlated with symptom severity for anxiety (ρ = 0.293), and depression (ρ = 0.322). Significantly higher parameters of depression and anxiety scores were observed in patients who were identified at risk for malnutrition (Me: 1, IQR: 4 vs Me: 0, IQR: 1, p < 0.001 for depression and Me: 3, IQR: 5 vs Me: 1, IQR: 4, p < 0.001 for anxiety, respectively)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Nardi et al. (2024), Italy, [49]	GIC (47%), Non-GIC (53%)	I (10.5%), II (11.8%), III (13.2%), IV (64.5%)	Consecutive patients evaluated by the Nutritional Support Unit, over 18 years of age, diagnosed with cancer (any type), and able to fill in the questionnaire used on admission. Exclusions: Patients with a history of mental disorders such as anxiety, depression, cognitive impairment, or taking antidepressants or were in a critical condition or had hearing problems that affected communication	AnX, D; CS; 51/25	M: 56.7, SD: 15.1, IC: 18 +	NN: < 3, MN: ≥ 3 based on NRS-2002 score	NN: 34.2%, MN: 65.8%	ND: < 8, BD: 8–10, D: ≥ 11 based on HADS-D; NAnX: < 8, BAnX: 8–10, AnX: ≥ 11 based on HADS-A	ND: 73.7%, BD: 18.4%, D: 7.9%, NAnX: 75.5%, BAnX: 14.5%, AnX: 10.0%	Linear regression adjusted to age and sex showed that higher NRS risk [aβ = 0.85; 95% CI (0.28–1.42); p = 0.004], and cachexia [aβ = 2.20; 95% CI (0.75–3.65); p = 0.003] were significantly associated with anxiety symptoms. The age and sex adjusted odds ratio of presenting anxiety symptomatology increased with each increase in NRS score and category [aOR = 1.91 (95% CI 1.34–2.77; p < 0.001), aOR = 3.75 (95% CI 1.45–8.55; p = 0.002)]. Cachexia was statistically significantly associated with high odds of anxiety symptomatology [aOR = 1.61 (95% CI 1.37–1.90; p < 0.001)]

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Singhal et al. (2024), United States, [52]	BRCA (12.8%), GIC (25.5%), GUC (14.6%), GC (6.3%), LUNG (25.9%), LYM (7.6%), OTH (7.4%)	III (8.7%), IV (88.7%)m OTH (2.6%)	Adult patients who were age ≥ 70 years, diagnosed with incurable lymphoma or solid tumor, receiving or planning to receive non curative cancer treatment (systemic therapy and/or radiation therapy), and had ≥ 1 impaired geriatric assessment impairment	AnX, D; CS; 276/264	M: 77.0, SD: 5.2, IC: 70 +	Aggregate definition: MNA-SF21 ≤ 11, BMI < 21 kg/m,2 or > 10% involuntary weight loss in the past 6 months	NN: 39.7%, MN: 60.3%	GDS-15, GAD-7, NCCN DT, cut-offs not reported	NR	On bivariate analysis, compared to patients with no nutritional impairment, those with nutritional impairment were more likely to report greater depression severity (mean GDS-15: 3.5 versus 2.5, p < 0.01), greater anxiety severity (mean GAD-7: 3.3 versus 2.2, p = 0.01), more distress (mean NCCN DT: 3.2 versus 2.5, p = 0.01). Multivariable linear regression models showed that impaired nutrition (yes vs no) according to aggregate definition was related to depression (β = 0.79, 95% CI 0.36 to 1.23), anxiety (β = 0.86, 95% CI 0.19 to 1.53), distress (β = 0.36, 95% CI − 0.09 to 0.82, marginally significant). MNA-SF ≤ 11 demonstrates the strongest associations with depression (β = 0.90, 95% CI 0.47 to 1.33), anxiety (β = 0.99, 95% CI 0.33 to 1.65), distress (β = 0.54, 95% CI 0.09 to 0.98)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Ting et al. (2024), Shanghai, China, [50]	COAD (30.0%), ESCA (36.4%), HBC and PAAD (10.0%) and BLCA (1.8%), LUNG (0.9%), OTH (3.6%)	NR	Patients who used parenteral nutrition, diagnosed clinically as tumors by pathological tissue; treated with preoperative radiotherapy, postoperative adjuvant chemotherapy, and radiotherapy; having normal mental, cognitive and other functions, which can effectively cooperate with the development of research. Exclusions: (1) those with contraindications to radiotherapy or no indications for chemotherapy; (2) Those with combined heart, liver, lung and other organ function damage; (3) Those with combined or previous digestive tract diseases; (4) Abnormal mental function; (5) Those who cannot effectively implement radiotherapy guidelines or stop radiotherapy without authorization; (6) Meet the supporters of parenteral nutrition	D; CS; 76/34	M: 56.4, SD: 5.6, R: 35–72	NN: <4, MN ≥ 4 based on PG-SGA score	NR	HAMD, cut-offs not reported	ND: 68%, D: 62%	After adjustment for age, education, monthly income per household, fear of disease progression, painful condition, diarrheal conditions, depression of patients who underwent parenteral nutrition after radical tumor resection was influencing factor of malnutrition (OR = 3.612, 95% CI 1.231, 8.756, P = .012)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Studies included only to systematic review										
Toliusiene et al. (2004), Lithuania, [16]	PRAD	III (100%)	Advanced prostate cancer patients aged 65 years and older receiving radiotherapy. Exclusions: chronic diseases that could affect nutrition; terminally ill patients; other malignancies	D; CS; 40/0	M: 71.5, R: 65–94	NN: ≥ 23.5, AMN: 17–23.5, MN: < 17 based on MNA score	NN: 40%, AMN: 50%, MN: 10%	ND: < 5, BD: 5–9, D: ≥ 10 based on GDS short form	ND: 28%, BD: 48%, D: 25%,	The MNA and GDS correlation analysis showed that higher score in nutrition was associated with a lower score in depressive symptomatology in advance prostate cancer patients ($r = -0.58$; $p < 0.01$) as well as in control group of patients with benign prostatic hyperplasia ($r = -0.46$; $p < 0.01$)
Britton et al. (2012), Australia, [14]	HNSC	I, II, III, IV (% NR)	Patients over 18 years, with primary HNSC undergoing radiotherapy. Exclusions: Patients who could not communicate in English and those being treated with palliative intention, defined as less than 20 fractions of radiotherapy	D; P; 50/8	M: 63.6, SD = 13.7, IC: 18 +	PG-SGA, cut-off points not reported	The median (IQR) for PG-SGA: 4 (6) at baseline (T1), 11 (10) at the end of treatment (T2), 6 (8) at 4 weeks post-treatment (T3)	ND: < 15 (none, mild or moderate D), D: ≥ 15 (moderately severe and severe D) based on PHQ-9; NAnX: 0–7, BAnX: 8–10, AnX: ≥ 11 based on HADS-A	ND: 89% D: 10%, NAnX: 79%, BAnX: 13%, AnX: 9% (T1); ND: 87% D: 13%, NAnX: 86%, BAnX: 7%, AnX: 7% (T2); ND: 89% D: 11%, NAnX: 81%, BAnX: 12%, AnX: 7% (T3)	After adjustment to clinical risk factors and psychological factors, backward elimination in the linear mixed models yielded baseline PHQ-9 but not HADS-A as the significant factor that contributed predictive value for PGA-SGA score. The clinical model, using categorical variables (PHQ-9 ≥ 15, HADS-A ≥ 11) also identified depression, as well as time, tumour site, as significant independent predictors of malnutrition at both end of treatment and 4 weeks post-treatment. At baseline patients with depression (PHQ-9 ≥ 15) had significantly higher values of PG-SGA than those without symptoms of depression (Mean: 16 vs 4)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Giannousi et al. (2012), Greek, [15]	LUNG	IV (100%)	Adult metastatic lung cancer patients (histologically or cytologically confirmed) treated with platinum-based doublet chemotherapy. Exclusions: Chronic diseases, concurrent infections those who were on any medication with that could interfere with the measured laboratory parameters, and/or those who were on chronic antidepressant therapy	AnX, D; CS; 102/20	Me: 65.5, R: 37–81	NN: ≥ 23.5, AMN: 17–23.5, MN: < 17 based on MNA score	NN: 30%, AMN: 61%, MN: 9%	ND: 0–7, BD: 8–10, D: ≥ 11 based on HADS-D; NAnX: 0–7, BAnX: 8–10, AnX: ≥ 11 based on HADS-A	ND: 65%, BD: 21%, D: 15%, NAnX: 55%, BAnX: 29%, AnX: 16%	Spearman's rank correlation analysis between MNA score and the depression and anxiety scale of HADS found a significant correlation only between MNA and depression (Spearman's rho, 0.275; p = 0.002) but not anxiety (Spearman's rho, 0.122; p = 0.179). Nutritional status of patients with metastatic lung cancer was found to be related to levels of depression, and acute phase response was also found to be related to levels of depression and anxiety, further supporting the role of cytokines as a common pathophysiologic mechanism

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Ma et al. (2013), Canada, [11]	HNSC	II (2%), III (23%), IV (75%)	Patients with advanced head-and-neck cancer (histology-confirmed)	AnX, D; CS; 80/19	M: 58.3, SD: 10.9, R: 23–85	NN: <4, MN: ≥4 based on PG-SGA score	NN: 39%, AMN: 25%, MN: 36%	Problem Checklist (as continuous)	ND: 51%, D: 49%, NAnX: 58%, AnX: 42%	The correlation between poorer nutrition status and level of psychological distress was significant r = 0.37 ($p < 0.001$). After controlling for the effects of psychosocial problems and pain in regression analysis, nutrition status remained a significant predictor of distress, explaining 3.8% of the variance in the distress scores of the patients ($p < 0.05$). 0.05). Depression was the problem most strongly associated with distress (r = 49, $p < 0.01$), but it was not correlated with nutritional status (r = 0.14, $p > 0.05$). Correlation between aggression and nutritional status was significant (r = 0.22, $p < 0.05$)

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Kim et al. (2016), Republic of Korea, [17]	HNSC	I (21.7%), II (10%), III (8.3%), IV (60%)	Previously untreated HNSC who underwent curative treatments. Exclusions: Patients who had initial distant metastasis, underwent previous treatment for HNSC, were lost to follow-up < 1 year after treatment, had a second primary cancer, had an unknown primary tumor site, or were aged < 18 or > 80 years	D; P; 206/35	Me: 60.0, R: 26–78, IC: 18–80	NN: ≤ 5%, MN: > 5% based on WL from pretreatment (additionally measured body weight, BMI, serum albumin, and hemoglobin levels)	NN: 73.4%, MN: 26.6%	ND: < 14, D: ≥ 14 based on BDI-II	ND: 75%, D: 25%,	The mean pretreatment serum albumin level was significantly lower in the depressive group than in the nondepressive group (3.9 vs 4.2 mg/dL; P < .001), but this difference was not present 1 month after treatment (3.7 vs 3.9 mg/dL; P = 0.142). BMI and other blood test results 1 month after treatment did not differ significantly between the 2 groups, and changes in these values from pretreatment to 1 month post-treatment also did not differ significantly between the 2 groups (all P > .05)
Alkan et al. (2018), Turkey, [18]	COAD (31%), STAD (9%), PAAD (6%), ESCA (2%), LIHC/CHOL (3%), LUNG (17%), BRCA (13%), GC (7%), HEAD (7%), OTH (6%)	I (1.0%), II (18%), III (21%), IV (59%)	Gastrointestinal and non-gastrointestinal (non-GIS) cancer patients treated with chemotherapy, 19–64 years—volunteers	AnX, D; CS; 59/45	M: 53.4, SD: 10.1, R: 19–64	PG-SGA, cut-off points not reported	NN: 42%, AMN: 27%, MN: 60%	ND: ≤ 6, D: ≥ 7 based on HADS-D; NAnX: ≤ 6, AnX: ≥ 10 based on HADS-A	ND: 52%, D: 48%, NAnX: 88%, AnX: 13%	Positively moderate and significant relationship was found between PG-SGA score and anxiety (r = .489, p < 0.001) and depression (r = .514, p < 0.001) scores based on Spearman correlation analysis

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Lin et al. (2021), China, [19]	A combination of different kinds of cancer	NR	Cancer patients undergoing chemotherapy recruited from the Huizhou Municipal Central Hospital. Exclusions: Situations that significantly influence olfactory function, including respiratory distress or active upper respiratory/sinus infection during the time of testing, congenital or traumatic anosmia, current or recent (past 6 months) smoking, and alcohol or substance dependence	D; CS; 106/95	M: 55.1, SD: 10.7	SNAQ, cut-off points not reported	Mean (SD) for SNAQ: 14.7 (2.8)	No categorisation, BDI as continuous	Mean (SD) for BDI: 3.5 (3.9)	Partial correlation controlling to age and gender showed that SNAQ score was negatively correlated with BDI score ($r = -0.224$, $P = 0.001$);

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Wang et al. (2022), Taiwan, [21]	Adenocarcinoma (73.3%), Signet-cell carcinoma (18.8%), GIST(7.9%)	0-I (35%), II (25%), III (40%)	Gastric cancer patients recruited from a medical center's general surgery or oncology clinics in Taiwan. Inclusions: (1) aged 20 or older, (2) diagnosed with gastric cancer, (3) having undergone total or subtotal gastrectomy, (4) time since surgery between three months and two years, (5) able to communicate in Taiwanese or Mandarin, and (6) able to eat orally. Exclusions: (1) needing long-term gastroesophageal feeding, (2) suffering severe mental disorders, (3) currently receiving chemotherapy or radiation therapy, and (4) with distant metastasis	D; CS; 53/48	M: 66.5, SD: 14.0, IC: 20 +	NN: ≥ 24 (48%), AMN: 17–23.5, MN: < 17 based on MNA score	NN: 48%, AMN: 44%, MN: 9%	CES-D	CES-D: Mean 9.6 points, SD = 7.6, R: 0–29	Results of Pearson's correlation analysis showed that nutritional status negatively correlated with depression severity ($r = -0.40$, $p < 0.001$). Participants with more severe symptoms, greater depression, and more difficulty preparing diets had worse nutritional status. However in stepwise multiple linear regression analysis, depression was not a significant predictor of malnutrition

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Overcash et al. (2023), United States, [20]	BRCA	I (42%), II (25%), III, (7%) IV (26%)	Women aged 70 years or older who were diagnosed with any stage of breast cancer and were receiving any type of treatment, including surgery, endocrine therapy, chemotherapy, or radiation therapy. Exclusions: Inability to read or understand English, or the inability to understand the consent process	D; CS; 0/72	M: 77.9, SD: 5.9, IC: 70 +	NN: 12–14, AMN: 8–11, MN: 0–7 based on MNA score	Mean ± SD for MNA: 12.21 ± 1.93	ND: < 5, D: ≥ 5 based on GDS-15	ND: 81%, D: 19%,	Correlation analysis showed that an increase in mean GDS scores was related to a decrease in mean MNA scores ($r = -0.32$, $p < 0.01$). However after adjustment for cancer stage, TUG test, ADL scale, pain in linear regression GDS wasn't the independent predictor of MNA mean scores (unstandardised β, 95% CI 0.07, − 0.13, 0.26)
Castro et al. (2024), Brasil, [22]	NR	NR	Patients under hemodialysis treated at three community-based hemodialysis centers with a confirmed cancer diagnosis	D; CS; n = 40	M: 69.7, SD: 2.4	NN: based on MIS	Mean ± SD for MIS: 15.1 ± 5.7	ND: < 6, BD: 7–17 (slightly depressed), moderate D: 18–24, severe D: > 25 based on HAMD	ND: 58.8%, D: 41.2% (moderate or serious)	Linear multiple regression disclosing association between MIS syndrome showed no correlation between MIS and the HAMD (β = 0.044, 95% CI − 0.325 to 0.413, p = 0.808) in hemodialysis cancer patients. In hemodialysis patients without cancer there was a positive correlation between MIS and HAMD

Table 1 (continued)

Author (Year), Setting	Cancer type	Cancer stage	Population	Psych. Outc; Design; M/F	Age, years	Nutritional status, definition and tool	Distribution of nutritional status	Mental status, definition and tool	Distribution of mental status	Main findings
Kacar et al. (2024), Turkey, [23]	GIC (31.8%), Non-GIC (68.2%)	NR	Adult patients diagnosed with cancer followed up in two periods, after the first course and the last course of chemotherapy while the chemotherapy treatment was in progress. Exclusions: pregnancy and breastfeeding, being diagnosed with diabetes, obesity, depression, and anxiety	AnX, D; CS; 24/20	M: 52.5, SD: 12.21, R: 18–64	PG-SGA, cut-off points not reported	Mean ± SD for PG-SGA: 3.86 ± 3.66 after the first cure	No categorisation, D and AnX: based on BDI and BAI as continuous	After the first cure Mean ± SD for BDI: 13.35 ± 6.61 in women, 16.75 ± 8.07 in men; for BAI: 16.15 ± 7.68 in women, 18.46 ± 8.99 in men	Linear regression determined that one-unit increase in the PG-SGA score, caused an increase of 0.809 points in the BAI score (ß = 0.389, p = 0.009) and a non significant increase of points in the BDI score (ß = 0.178, p = 0.247)
Umławska et al. (2024), Poland, [24]	LUNG (NSCLC)	III, IV	Elderly patients with advanced non-small-cell lung cancer (NSCLC). Eligible participants were those scheduled for a minimum of two palliative chemotherapy courses (vinorelbine monotherapy or platinum-based doublets with vinorelbine or docetaxel) or chemoradiotherapy (platinum doublets with vinorelbine and sequential radiotherapy), aged ≥ 65 years, and with an ECOG/WHO performance level of 0–2. Exclusions: patients with brain metastases	D; P; 32/13	M: 70.0, SD: 4.5, R: 65–82	NN: ≥ 24, AMN: 17–23.5, MN: < 17 based on MNA	NN: 60%, AMN: 36%, MN: 4% at baseline; NN: 51%, AMN: 42%, MN: 7% at follow-up	ND: 0–4, BD: 5–9 mild, 10–14 moderate, D: 15–19 moderately severe, and 20–27 severe depression based on PHQ-9	ND: 44% (none or minimal), BD: 40% (mild or moderate), D: 16% (moderately severe or severe) at baseline; ND: 42%, BD: 49%, D: 9% at follow-up	Correlation analysis between MNA score and PHQ-9 score at baseline and at follow-up, consistently showed negative association (higher MNA means better nutritional status): r = − 0.769, r = − 0.513. Similar association was found for pre-post changes. The improvement of patients'mental condition was related strictly to the improvement of nutritional status (r = − 0.589, P < 0.001)

Table 1 (continued)

CS Cross sectional, *CC* case–control, *M* mean, *NAC* Neoadjuvant chemotherapy, *NR* not reported, *P* prospective, *PosAnX* Possible anxiety/at risk of anxiety, *PosD* Possible depression/at risk of depression, *SD* standard deviation; *R* range, *F/M* number of female/number of male

Nutritional status: abPG-SGA—Abridged version of the PG-SGA; ALB—Serum albumin; AMC—Arm muscle circumference; AMN—At risk of malnutrition/moderate risk of malnutrition; CaX—cachexia; CONUT—Controlling Nutritional Status; GLIM criteria—Global Leadership Initiative on Malnutrition; K—Total body potassium; MIS—Malnutrition-inflammation score; MN—Malnutrition/high risk of malnutrition; MNA—Mini-Nutritional Assessment; MNA-SF—Mini Nutritional Assessment Short Form; MUST—Malnutrition Universal Screening Tool; MUST—Malnutrition Universal Screening Tool; NCaX—Non-cachexia; NI—Nutritional Indicators; NN—Normal nutrition status/low risk of malnutrition; NRI—Nutritional Risk Index; NRS2002—Nutritional Risk Screening 2002; NSI checklist—Nutrition Screening Initiative; PG-SGA—Patient-Generated Subjective Global Assessment; PNI—Prognostic Nutritional Index; SMI—Skeletal muscle index; SNAQ—Simplified Nutritional Appetite Questionnaire; TSF—Triceps skinfold; WI—Weight index; WL—Weight loss

Mental status: AnX—Anxiety; BAI—Beck Anxiety Inventory; BAnX—Borderline anxiety; BD—Borderline depression; BDI—Beck Depression Inventory; BEDS—Brief Edinburgh Depression Scale; CES-D—10-item version of the Center for Epidemiological Studies Depression Scale; CPPRS11—the total sum of the 11 items of CPRS; CREAT—creatinine; D—Depression; DT—Distress Thermometer; ELCAPA—ELderly CAncer PAtient survey; ESAS-r—Edmonton Symptom Assessment System—revised; GAD-7—Generalized Anxiety Disorder-7; GDS-15—Geriatric Depression Scale-Short Form; HADS—Hospital Anxiety and Depression Scale; HAMD—Hamilton Depression Scale; mini-GDS—Mini-Geriatric Depression Scale; ModD—Moderate Depression; MMSE—Mini Mental State Examination results; NCCN DT—National Comprehensive Cancer Network distress thermometer; ND—Not depressed/mild depression; PHQ-9—Patient Health Questionnaire-9; PSSCAN—Psychosocial Screen for Cancer; PrCHECK – Problem Checklist; S-AI—State Anxiety Questionnaire; SAS—Anxiety self-assessment scale; SCL-10—Hopkins Symptoms Check List-10; SDS—Self-rating Depressive symptoms Scale; SevD—Severe Depression; SGDS-K—Short Form of the Geriatric Depression Scale; SPSI—The sum score of sadness, pessimistic thoughts, and suicidal thoughts; STAI—The State-Trait Anxiety Inventory; T-AI—Trait Anxiety Questionnaire

Cancer types: BM—Bone Metastases; BRCA—Breast Cancer; CHOL—Bile Duct Cancer; COAD—Colon Cancer; COADREAD—Colon and Rectal Cancer; DC—Digestive Tract Cancer; EGJC—Esophagogastric Junction Cancer; ESCA—Esophageal Cancer; GC—Gynecological; GIC—Gastrointestinal Tract Cancer; GIST—Gastrointestinal Stromal Tumors; GUC—Genitourinary Cancer; HBC—Hepatobiliary cancer; HC—hematologic cancer; HL—Hodgkin lymphoma; HNSC—Head and Neck Cancer; LIHC—Liver Cancer; LUNG—Lung Cancer; LYM—Lymphoma; NDC—Non-digestive Tract Cancer; NHL—Non-Hodgkin Lymphoma; NSCLC—Non-Small-Cell Lung Cancer; NPC—Nasopharyngeal Cancer; OTH—Other sites cancer; OV—Ovarian Cancer; PAAD—Pancreatic Cancer; PRAD—Prostate Cancer; SARC—Sarcoma; STAD—Stomach Cancer; STT—Soft Tissue Tumour; UGIC—Upper Gastrointestinal Tract Cancer; UTC—Urinary Tract Cancer

diagnostic and screening tools were used to evaluate psychological status such as HADS (in 13 studies), BDI (in 6 studies), GDS (in 6 studies), PHQ (in 3 studies), HAMD (in 4 studies), and others (in 9 studies). Different methods for nutrition assessment in patients with tumours were applied, among which the most frequent were PG-SGA (in 14 studies), MNA (in 10 studies), NRS-2002 (in 5 studies), GLIM criteria (in 3 studies), and others (in 9 studies). 9 trials restricted the population to advanced tumours only, while the remaining 32 looked at different stages of the disease (of which 4 did not specify tumour stage). Among selected articles 29 were quantitatively summarised in the meta-analysis, and 12 were used only in systematic review. Overall, the entire sample amounted to 9,300 cancer patients, therein 8,133 in the articles included in meta-analysis. When restricted to studies with available data on the distribution of nutritional status, the prevalence of nutritional impairment was estimated at 52%. Similarly, it was shown that 30% and 26% of oncology patients had symptoms of depression and anxiety, respectively. The high quality of the reports (scored over 5 for cross-sectional and over 7 for case–control and prospective studies) was assessed in about half of the studies (21 articles) included in this systematic review and 16 out of 29 included in the meta-analysis (Supplementary Table 4-Supplementary Table 6).

Comparison of the risk of psychological disorders between extreme categories of nutritional status

The meta-analysis of the association between nutritional status and depression and anxiety disorder was based on 11 and 9 studies, respectively (Fig. 1, Table 2). Compared with the patients with normal nutritional status, a group of malnourished patients had 3.23 times and 1.87 times larger risk of each aforementioned outcome, respectively (RR = 3.23, 95% CI 2.39 to 4.38 for depression, RR = 1.87, 95% CI 1.48 to 2.37 for anxiety; Table 2, Fig. 1). Only little or no heterogeneity was detected for both depression and anxiety ($I^2 = 22.5\%$, $P = 0.229$ for depression and $I^2 = 0.0\%$, $P = 0.581$ for anxiety; Fig. 1). The exclusion of one study at the time did not considerably change pooled results (RRs ranged from 2.95 to 3.55 for depression when Sanchez-Torralvo, 2022 and Sun, 2020 study, respectively was omitted, and RRs ranged from 1.76 to 2.00 for anxiety when Williams, 2020 and Soria-Utrilla, 2022 study, respectively was omitted; Supplementary Fig. 2A and 2B). The inspection of funnel plots and the results of the Egger's test revealed some evidence of asymmetry in the analysis of depression (P = 0.002; Supplementary Fig. 3): trim-and-fill analysis adjusting for potential publication bias by complementing 4 missing studies confirmed the previous findings showing slightly lower effect of nutritional impairment on depression (RR = 2.71, 95% CI 1.94 to 3.77; Table 2). Subgroup analysis for each outcome showed substantially stable results, with strong and significant pooled effect for all tested subgroups in the case of depression and some minor loss of significance in certain subgroups in the analysis of anxiety, mostly due to the very limited number of studies included (Supplementary Table 7).

Comparison of the risk of malnutrition between extreme categories of psychological status

Due to the possible bidirectional association between nutritional and psychological status in cancer patients, following the design of studies in the original articles, we alternatively examined how psychological status influences malnutrition. Meta-analyses included 12 studies on depression, and 2 studies on anxiety disorder, respectively (Supplementary Fig. 4, Table 2). Compared with the patients with normal psychological status, a twofold larger risk of malnutrition was detected in a group of patients with depression disorder (RR = 2.01, 95% CI 1.62 to 2.49 for depression). Anxiety was not significantly linked with poor nutritional status (RR = 1.38, 95% CI 0.68 to 2.80; Table 2, Supplementary Fig. 4), however, only 2 studies were available to examine this relationship and therefore subgroup, influential and publication bias analysis could not be performed. High heterogeneity was detected for both depression and anxiety as exposure ($I^2 = 87.8\%$, $P < 0.001$ for depression and $I^2 = 73.4\%$, $P < 0.001$ for anxiety; Supplementary Fig. 4). In the analysis of depression, in most cases, excluding one study at a time from the analysis only slightly reduced the pooled RR, except for two studies the omission of which significantly increased the size of the estimated effect (RR = 3.19, 95% CI 1.84 to 5.54 for Nho, 2014 and RR = 3.20, 95% CI 1.88 to 5.42 for Hong, 2016; Supplementary Fig. 2C). The inspection of funnel plots and the results of Egger's test revealed some evidence of asymmetry (P < 0.001; Supplementary Fig. 3B). However, pooled RR after complementing 6 missing studies in trim-and-fill analysis still showed a significantly higher risk of malnutrition (of 39%) in depressed patients compared with those without the mental disorder (RR = 1.39, 95% CI 1.13 to 1.71, Table 2). Additional subgroup analyses revealed that the level of adjustment and tumour anatomical site have an impact on the estimated size effect. Slightly reduced RR was observed in the meta-analysis of studies in which results were adjusted to potential confounders (RR = 1.56, 95% CI 1.26 to 1.92) and RR lost significance in populations with sex-related cancers (RR = 1.41, 95% CI 0.73 to 2.73) as well as in studies relying on the BDI as a psychological screening tool and a nutritional screening tools other than the PG-SGA and the MNA (Supplementary Table 8).

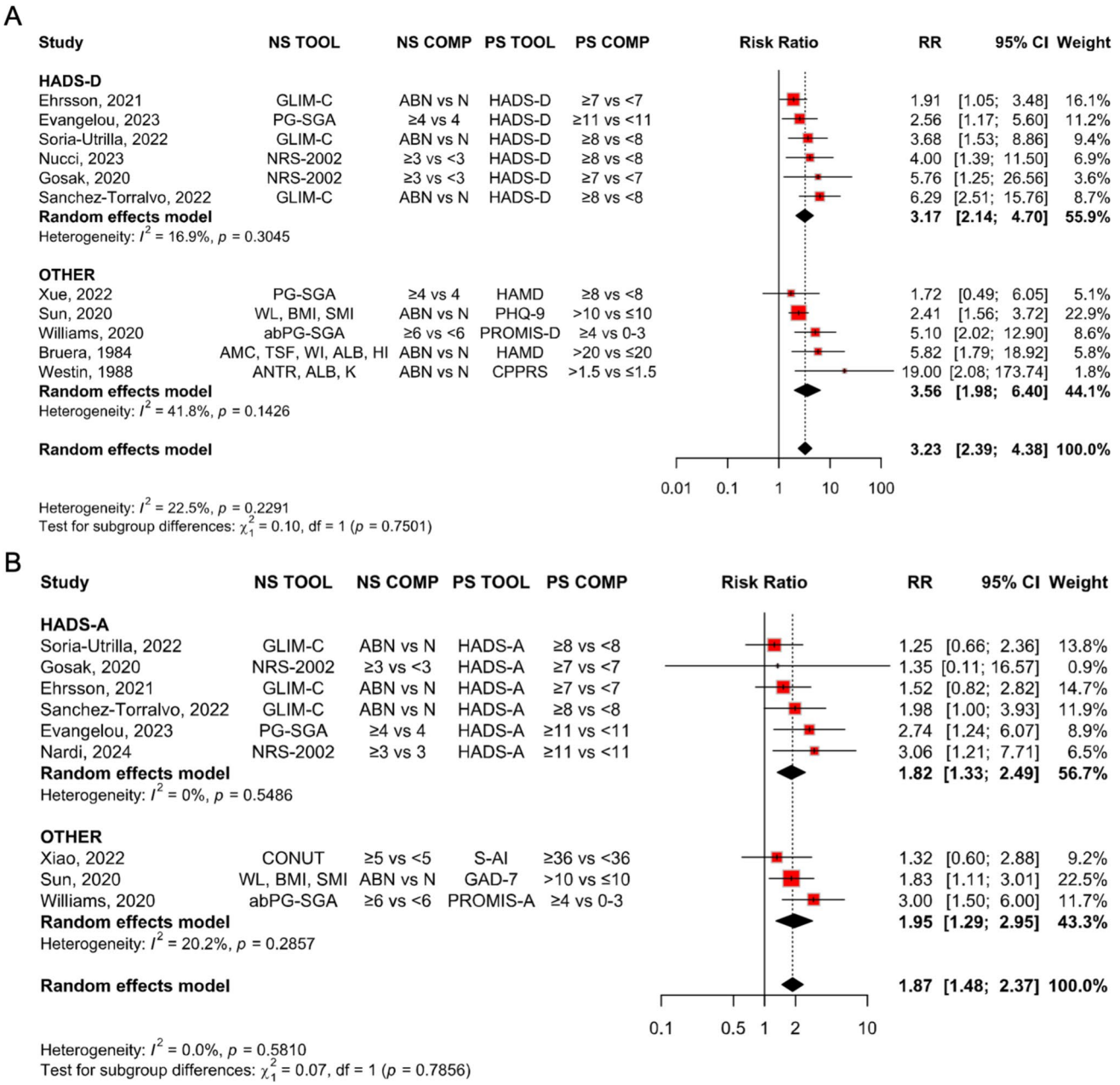

Fig. 1 Graphical representation of the association between nutritional status and **A** depression **B** anxiety: meta-analysis depicting relative risk of depression or anxiety for the patients from the highest risk of nutritional impairment compared with the lowest risk. Red squares and horizontal black segments reflect point estimates and confidence intervals of relative risks in individual studies, respectively, while black diamonds depict pooled RRs with 95% CIs. Abbreviations: NS TOOL—nutritional tool, NS COMP—compared extreme categories of nutritional status, PS TOOL—psychological tool, PS COMP—compared categories of psychological status, ABN vs N—abnormal vs normal values, GLIM-C- GLIM criteria

Comparison of means of psychological scores between extreme categories of nutritional status

Meta-analysis of standardised mean differences of psychological scores between extreme categories of nutritional status revealed significantly higher scores in individuals with nutritional impairment compared with those with normal nutritional status (SMD = 0.69, 95% CI 0.50 to 0.88 for depression based on 11 studies and SMD = 0.54, 95% CI 0.26 to 0.82 for anxiety based on 9 studies). Studies using HADS-D (SMD = 0.85, 95% CI 0.37 to 1.32) and BDI-II (SMD = 0.79, 95% CI 0.60 to 0.982) as psychological screening tools, as well as low-quality studies (SMD = 0.92, 95% CI 0.51 to 1.33 vs. SMD = 0.44, 95% CI 0.37 to 0.51)

Table 2 Main results of meta-analysis exploring the association between nutritional status and depression and anxiety

Analysis	N_{comp}	RR/SMD [95% CI]	P	I^2 [%]	P_{het}
Comparison of risk depression and anxiety disorders across extreme categories of nutritional impairment					
Depression					
Main analysis	11	3.23 [2.39; 4.38]$^{\$}$	< 0.001	22.5	0.229
Trim and fill analysis	15	2.71 [1.94; 3.77]$^{\$}$	< 0.001	40.7	0.051
Anxiety					
Main analysis	9	1.87 [1.48; 2.37]$^{\$}$	< 0.001	0	0.581
Trim and fill analysis	10	1.81 [1.44; 2.28]$^{\$}$	< 0.001	0	0.543
Comparison of risk nutritional impairment across extreme categories of depression and anxiety					
Depression					
Main analysis	12	2.01 [1.62; 2.49]$^{\$}$	< 0.001	87.8	< 0.001
Trim and fill analysis	18	1.39 [1.13; 1.71]$^{\$}$	0.002	86.9	< 0.001
Anxiety					
Main analysis	2	1.38 [0.68; 2.80]$^{\$}$	0.379	73.4	0.053
Trim and fill analysis	–	–	–	–	–
Comparison of mean scores of depression and anxiety across extreme categories of nutritional status					
Depression					
Main analysis	11	0.69 [0.50; 0.88]$^{\&}$	< 0.001	86.4	< 0.001
Trim and fill analysis	16	0.44 [0.23; 0.64]$^{\&}$	< 0.001	90.7	< 0.001
Anxiety					
Main analysis	9	0.54 [0.26; 0.82]$^{\&}$	< 0.001	93	< 0.001
Trim and fill analysis	12	0.70 [0.45; 0.96]$^{\&}$	< 0.001	93.9	< 0.001

N_{comp}—number of comparisons synthetized in individual analyses, I^2—heterogeneity statistic, P_{het}—P for heterogeneity, RR—relative risk, SMD—standardised mean difference, $^{\$}$Designated values present RRs, $^{\&}$Designated values present SMDs

showed significantly higher size effects reflecting more negative impact of malnutrition on depression (Table 2, Fig. 2). Moreover, subgroup analysis restricted to studies applying GLIM criteria as a nutritional screening tool assessed the detrimental effect of malnutrition on anxiety on a lower level than the remaining studies (SMD = 0.19, 95% CI 0.04, 0.35; Supplementary Table 9), however, the result was still significant. The omission of any of the studies did not change significantly the value of pooled RR or reduce heterogeneity (Supplementary Fig. 5). Some evidence of asymmetry of funnel plot for depression was detected ($p < 0.05$ for Egger's test; Supplementary Fig. 3C), after adding 5 missing studies in sensitivity trim-and-fill analysis positive association between malnutrition and depression was confirmed (SMD = 0.44, 95% CI 0.23 to 0.64; Table 2).

Correlational studies on the association between nutritional score and psychological score and narrative review of the studies not included in meta-analysis

Twelve studies [11, 14–24] did not contain data that needed to be included in a quantitative synthesis and were described only in narrative form. Detailed characteristics of these studies are presented in Table 1. Shortly, four articles investigated both depression and anxiety and 8 depression alone. Patients with various types of cancers were recruited in four studies, while in the other 8 specific tumour sites was a condition enabling for inclusion [head and neck (n = 3), lung (2), prostate (n = 1), breast (n = 1) and gastric (n = 1) cancers]. Various psychological screening tools were applied in individual studies, however, mostly MNA (n = 5) and PGA-SGA (n = 4) were used to measure nutritional impairment. The examined patients were from European (n = 3), Eastern (n = 5) and Western (n = 4) countries. Most studies were concentrated on various stages of tumour (n = 8) and 4 restricted populations only to advanced cancer patients.

Eleven out of 12 studies not included in the meta-analysis and two additional included in meta-analysis investigated scores of depression and/or anxiety as well as scores of nutrition as continuous variables and presented measures of correlation between them. Summary of the correlation (Pearson's or Spearman) and standardised linear regression coefficients extracted from all studies included in this systematic review are graphically depicted in Fig. 3. 10 out of 13 studies on depression and 5 out of 6 studies on anxiety, indicated a significant positive correlation between worse nutritional score and worse mental score. Five studies presented results adjusted to potential confounders [14, 19, 20, 22, 23], all showed the

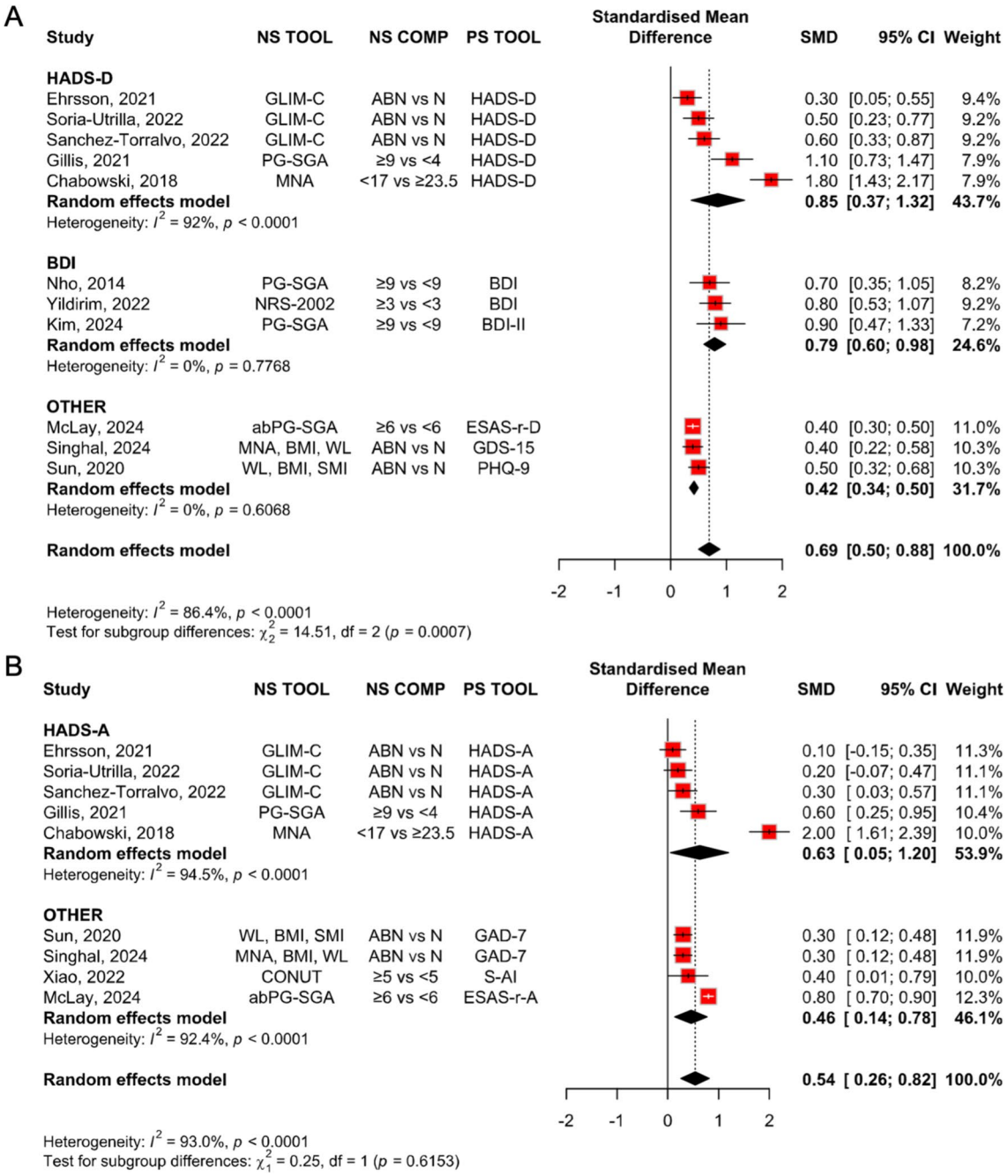

Fig. 2 Graphical representation of the association between scores of **A** depression **B** anxiety and nutritional status: meta-analysis depicting standardised mean differences in psychological outcomes between patients from the highest risk of nutritional impairment compared with the lowest risk. Red squares and horizontal black segments reflect point estimations and confidence intervals of standardised mean differences in individual studies, respectively, while black diamonds depict pooled SMDs with 95% CIs. Abbreviations: NS TOOL—nutritional tool, NS COMP—compared extreme categories of nutritional status, PS TOOL—psychological tool, PS COMP—compared categories of psychological status, ABN vs N—abnormal vs normal values, GLIM-C- GLIM criteria

same direction of the association, however only three of them depicted statistically significant correlations between scores. Specifically, baseline PHQ-9, but not HADS-A, was the significant predictor for PGA-SGA score; SNAQ was negatively correlated with BDI; and increase in the PG-SGA was associated with increase in the BAI but not in BDI score.

Finally, one study [17] was not included in the meta-analysis because separately examined some aspects of nutritional status, such as albumin level, weight loss, and BMI, but did

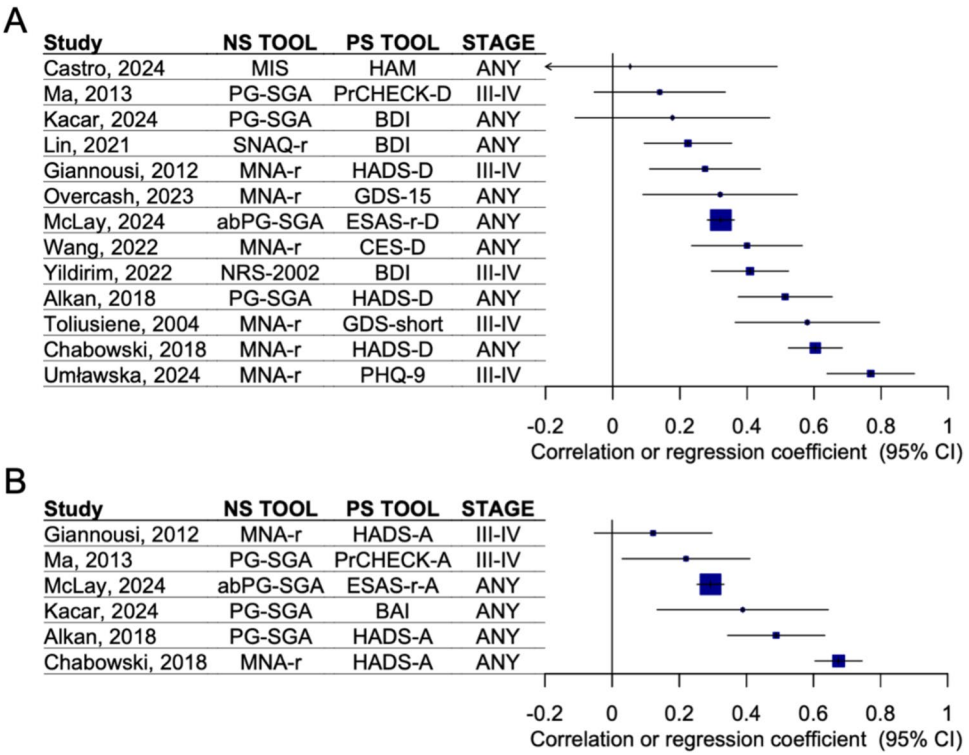

Fig. 3 Graphical representation of the association between scores of **A** depression **B** anxiety and nutritional score depicting correlation and regression coefficients extracted from individual studies. Blue squares and horizontal black segments reflect point estimations and confidence intervals of correlation coefficients or standardised regression coefficients in individual studies, respectively. Abbreviations: NS TOOL—nutritional tool, PS TOOL—psychological tool, STAGE—cancer stage. All nutritional scales were transformed if needed by multiplying their result by minus one, such that higher scores always reflect worse nutritional status; nutritional tools (MNA and SNAQ) for which such transformation was applied are denoted by the suffix "-r". Higher scores of mental tools used in original articles always meant higher risk of mental disorder

not use any composite score to measure comprehensively the construct. It was shown that in patients with HNSC, the mean pretreatment serum albumin level was significantly lower in the depressive group than in the non-depressive group (3.9 vs 4.2 mg/dL; $P < 0.001$), but this difference was not present 1 month after treatment (3.7 vs 3.9 mg/dL; $P = 0.142$).

Discussion

In this comprehensive meta-analysis and systematic review summarising the evidence from 41 observational studies on patients with different types and stages of cancer, we found a significant association between malnutrition and psychological outcomes, such as anxiety and depression. We compared the risk, as well as the mean scores of both psychological outcomes between extreme categories of nutritional status, consistently revealing their positive correlation. Our study showed substantially homogeneous results, with some fluctuations in size effects and minor loss of significance in certain subgroups (e.g., in studies on sex-related cancers in analysis of the effect of depression on nutritional impairment), dependent on specific analysis, and mostly due to the limited number of individual comparisons included. To the best of our knowledge, this is the first meta-analysis to examine the association between nutritional status and psychological disorders, particularly depression and anxiety, in cancer patients.

sThe psychological and physical burden of chronic diseases can cause suboptimal food intake and also increased levels of mental distress. A statistically significant direct relationship between the risk of undernutrition and the risk of depression has been found in hospitalised patients [54]. Undeniably, specifically in oncology populations poor nutritional status and emotional suffering are common. The relationship between depression, anxiety, and cancer outcomes remains ambiguous. The findings from a meta-analysis conducted by Wang et al. (2020) revealed a correlation between both clinically diagnosed psychiatric conditions, and diminished survival outcomes in cancer patients [55]. Linden et al. (2012) identified oncology populations most in need of psychosocial support and showed that clinical anxiety and depression affected 19.0% and 12.9% of

patients, respectively. Individuals with lung, gynecological, and hematological cancers reported the highest levels of distress at diagnosis. The cited study also found that women exhibited larger rates of anxiety and depression than men, often two to three times higher. Furthermore, emotional distress was found to be inversely related to age in certain types of cancers. Over half of patients under 50 and women across all cancers were suffering from subclinical or clinical anxiety [12]. In our meta-analysis, the estimated prevalence of depression and anxiety was at a level of 30% and 26%, respectively. Comparable, in an outpatient oncology population, Zeilinger et al. estimated that a significant percentage of patients manifested signs of depression (29.7%) and anxiety (35.2%), with about half of them showing symptoms strongly indicative of a very likely condition. The frequency of both psychological disorders was found to vary between tumour anatomical sites and the highest levels were noted in the populations suffering lung, brain, kidney/bladder, pancreas and head and neck cancers, while the lowest were observed in patients with testis, haematological, colon/rectum and breast cancer [56]. It should be emphasised that signs of depression and anxiety are mainly associated with advanced disease, as well as a low educational level, with prevalence rates appearing to be comparatively elevated in low- and middle-income countries [57]. It was postulated that the over-representation of depressive symptoms among cancer patients with weight loss indicates that the mental state is associated with physical impoverishment rather than with the malignant condition per se [26]. At the same time in an intervention pilot trial comprising the oral cavity, pharynx and larynx cancer patients undergoing radiotherapy and being at greater nutritional risk, a significant reduction in the PG-SGA and lower mortality was observed in favour of the subjects receiving motivational interviewing and cognitive behavioural therapy compared to controls treated as usual [58]. Moreover, in another intervention study conducted on patients with advanced gastric cancer who underwent chemotherapy, personalized nutrition enhanced the quality of life and had a favorable effect on psychological resilience compared with routine management, and when combined with acceptance and commitment therapy additionally alleviated the side effects of chemotherapy [59]. In our meta-analysis, we confirmed the observation that the relationship between malnutrition and worsened mental status may be bidirectional, as suggested by some included studies.

Cancer has been shown to affect patients'quality of life, adherence to treatment and overall care [21, 60, 61]. Adequate and balanced nutrition [62] is therefore critical to maintain physical and mental well-being during cancer treatment and to achieve better survival outcomes [16, 21, 63, 64]. In oncology populations, disturbances in nutritional status are associated with various factors, including the presence of cancer itself, the therapeutic interventions used, changes in metabolic processes, dietary imbalances, and decreased physical activity [65]. Furthermore, age and stage of disease have been shown to have an impact on the deterioration of nutritional status during treatment [30].

The findings from the present meta-analysis indicate a strong association between malnutrition and an increased risk of depression and anxiety in the oncology population. A comparison of patients with normal nutritional status against those with malnutrition revealed a more than threefold elevated risk of depression (RR = 3.23, 95% CI 2.39 to 4.38) and a nearly twofold heightened risk of anxiety (RR = 1.87, 95% CI 1.48 to 2.37). Subgroup analyses consistently showed a higher risk of psychological disorders in malnourished patients, though some subgroups displayed variations in statistical significance. The use of various self-reported depression screening tools revealed that the correlation between nutritional status and psychological well-being remains robust irrespective of the assessment method. Taking into account a direct link between distress and specific disorders of emotion regulation such as depression and anxiety, these results align with previous research indicating a strong positive correlation between Distress Thermometer and PG-SGA scores across various types of cancer patients and specifically in patients with advanced head-and-neck cancer [11, 66]. Prior studies have consistently shown that malnourished individuals are at a significantly higher risk of depression. Subjects suffering from chronic illnesses, including cancer and inflammatory bowel disease, are predisposed to both malnutrition and depression. Nevertheless, certain studies reported associations that were less pronounced or yielded non-significant findings in specific cancer subgroups within the context of mental health disorders. These variations can be attributed to differences in study design, sample size, or the methods employed to assess nutritional and psychological status and were reflected in high heterogeneity in some of our sub-analyses. For instance, among studies included in the current meta-analysis, Ehrsson et al. (2021) found a significant relationship between malnutrition and depression but not with anxiety [38]. Similarly, a study by Britton et al. (2012) reported that while depression was a key predictor of malnutrition risk at various stages of cancer treatment, anxiety did not appear to have a similar impact [14]. This suggests that while malnutrition is a critical risk factor for depression across various cancer populations, its impact on anxiety may vary depending on additional clinical and demographic factors.

The majority of participants from the articles included in this meta-analysis were over 60 years of age. Studies consistently show a high prevalence of both malnutrition and depression among the elderly. For instance, in a study conducted in Bangladesh by Alam et al. (2021), 84% of elderly participants exhibited symptoms of depression, and those who were malnourished had a significantly increased risk of

depression (OR = 4.05) [67]. Similarly, another study found that 43.62% of older adults were depressed, and 48.01% of these were malnourished or at risk of malnutrition [68]. In a research conducted by Asma et al. (2023) among hospitalized elderly patients, 28.6% were undernourished, 37.3% were depressed and a significant relationship between both conditions was found $p < 0.001$) [54]. In a study of older Chinese adults, malnourished individuals were 31% more likely to be depressed compared to those who were not malnourished [69]. Malnutrition and depression are closely related health issues that are particularly common among older people and those with chronic diseases. Malnutrition, mainly in older adults has been demonstrated to be associated with cognitive decline, which has been shown to exacerbate depressive symptoms by impairing the ability to cope with stress and reducing overall mental resilience [70]. A decrease in emotional status has been identified as both a cause and a consequence of malnutrition in those older adult groups. Poor nutritional status has been shown to lead to poor emotional well-being, creating a vicious cycle where depression worsens malnutrition and vice versa [67, 70].

It is widely recognized that malnutrition has a significant impact on the development of depression, with this influence being exerted through a number of different mechanisms and populations. It is evident that malnutrition can induce changes in the hypothalamic–pituitary–adrenal (HPA) axis, which can result in elevated levels of stress hormones, such as cortisol, which have been shown to be associated with depression [71]. Malnutrition can result in deficiencies in essential nutrients such as vitamins and minerals, as well as macronutrients. These nutrients are crucial for brain functioning, for instance, omega-3 fatty acids play a key role in maintaining the structure and function of brain cell membranes, while specific amino acids like tryptophan and tyrosine serve as precursors for neurotransmitters such as serotonin and dopamine, respectively [72]. These neurotransmitters play a significant role in mood regulation, and their deficiency can contribute to depressive symptoms [54, 70]. Poor nutritional status can lead to physical health problems such as muscle atrophy, impaired immune function, and chronic diseases, which can, in turn, increase the risk of depression. The physical decline associated with malnutrition can reduce an individual's ability to engage in daily activities, leading to feelings of helplessness and depression [54, 73, 74]. Malnutrition is associated with reduced physical function, which can lead to a loss of autonomy and increased dependency on others. This loss of independence can contribute to feelings of anxiety and stress [70].

The interaction between malnutrition and depression characterised by a bidirectional relationship, particularly in the context of psychological support for nutritional interventions for cancer patients, has been emphasised by many authors [11, 43, 53]. It is not clear which is the cause and which is the effect, which we addressed in our meta-analysis. Our findings demonstrated that cancer patients diagnosed with depression exhibited a twice elevated risk of compromised nutritional status in comparison with the control group. No such correlation was observed in relation to anxiety, although only two studies were identified, hence this result should be treated with caution.

Depression has been shown to be associated with more severe nutritional impact symptoms (NIS), including anorexia and early satiety, which can result in reduced food intake [75]. Patients with higher NIS scores have been found to report lower food intake, highlighting the impact of depression on their ability to consume adequate calories. Constipation and oral ulceration, further exacerbating the nutritional status, have been found to be associated with depression [75, 76]. The pathophysiology of cancer cachexia, a condition characterised by significant weight loss and muscle atrophy, involves complex mechanisms beyond simple caloric deficiency. Depression has been shown to exacerbate cachexia by affecting inflammatory and catabolic pathways, consequently leading to further reductions in caloric intake [77]. Depression has been demonstrated to enhance weight loss in cancer patients. For instance, in patients diagnosed with head and neck cancer, those who also suffered from depression experienced more significant weight loss compared to those who did not suffer from depression. This weight loss was also associated with lower levels of leptin, a hormone involved in appetite and weight regulation [78]. Depression has been shown to exacerbate the side effects of chemotherapy, including nausea or vomiting, which can result in weight loss [79]. The type and stage of cancer have been demonstrated to influence the manner in which depression affects weight. For instance, patients diagnosed with breast cancer who are undergoing chemotherapy often experience weight gain, which is associated with a more unfavorable prognosis [80]. Depression significantly affects weight changes in cancer patients, with both weight loss and weight gain. They are likely to depend on various factors such as gender, cancer anatomical site, and side effects of treatment. Addressing depressive symptoms through appropriate psychological and pharmacological interventions is crucial for improving the overall well-being and quality of life of cancer patients [8].

Many studies demonstrated associations between diet quality and mental health. A previous meta-analysis showed that dietary interventions represent a promising strategy for reducing depressive symptoms in the general population [81]. Dietary interventions significantly reduced depressive but not anxiety symptoms. Moreover, greater benefits were observed in females for both depression and anxiety [81]. The findings suggest that a healthy dietary pattern (diet rich in fruits, vegetables, whole grains, fish, olive oil, low-fat dairy, and antioxidants, with

limited animal food consumption), is associated with a lower risk of depression, which confirmed other meta-analyses [82, 83]. Conversely, a Western-style diet (high in red and processed meat, ultra-processed food, refined grains, sweets, high-fat dairy, butter, potatoes, and high-fat gravies, with low fruit and vegetable intake) may increase depression risk [84, 85]. Strong evidence specifically supports the Mediterranean diet, dietary inflammatory index (DII), and higher scoring in the healthy eating index (HEI) in reducing depression risk [86]. Adherence to a healthy diet, particularly the Mediterranean diet, or avoiding a pro-inflammatory diet may offer protective effects against depression in observational studies [86]. Although there is a corroborated relation between a healthy diet and a reduced likelihood of developing depressive symptoms, there is no unequivocal support for the hypothesis that dietary influences play a direct role in the etiology of depression [87].

However, the overall nutritional status on mood and psychological well-being remains unclear. Deficiencies in specific nutrients, such as n-3 polyunsaturated fatty acids (PUFAs), are linked to increased depressive and anxiety-like behaviors. Conversely, diets characterised by a high proportion of n-6 PUFAs have been linked to an increased prevalence of depressive symptoms [71, 82, 88]. Conversely, high consumption of sugar-sweetened beverages was associated with an increased risk of depression [88]. Significant weight loss, associated with the risk of malnutrition, has been linked to increased anxiety and depression, exacerbated disease progression and diminished quality of life [35]. One potential mechanism for mental health deterioration may be related to diet and malabsorption. Identified changes in vitamin B12 levels and body composition during a patient's treatment contribute to anxiety [23]. Folic acid and vitamin B12 deficiencies have been demonstrated to impair homocysteine metabolism, potentially contributing to neurological and psychiatric disorders by impairing neurotransmitter synthesis and neuronal plasticity [89–91]. While some studies have indicated a correlation between vitamin D deficiency and depression, the evidence for an association with anxiety remains inconclusive [92–94]. It is crucial to acknowledge that patients grappling with severe symptoms, unemployment, and dietary challenges are more susceptible to malnutrition [21], however, an improvement in nutritional status is associated with better mental health outcomes [24].

The combination of malnutrition and depression can significantly reduce the quality of life. In cancer patients, poor nutritional status was found to be inversely associated with functional capacity and quality of life, with depression and anxiety mediating these effects [43]. Malnutrition and depression together increase healthcare costs, highlighting the economic burden of these comorbid conditions [69]. For patients with chronic conditions like cancer, psychosocial support and nutritional interventions are crucial to improve quality of life and manage treatment symptoms [38].

Several limitations should be taken into account despite the strengths of this meta-analysis. First, the pooled results might have been affected by the heterogeneity regarding study designs, cancer anatomical sites, and tools used for assessing both nutritional and psychological status. Second, the direction of the relationship between malnutrition and psychological disorders is unclear. Although malnutrition may be an important risk factor for depression and anxiety, it is also plausible that experiencing psychological distress may cause a reduction in nutritional intake, leading to malnutrition. As much as possible, we accounted for this in our research by performing analyses in both directions, however, the real nature of this association underscores the importance of longitudinal studies to clarify causality. Third, half of the papers included in the meta-analysis did not control for potential confounders, so we cannot exclude that better-designed studies with more rigorous control of covariates could weaken the results.

In conclusion, the findings emphasize the critical need for integrating nutritional assessments into the routine care of cancer patients, particularly those at risk of psychological distress. Early identification and intervention for malnutrition may help mitigate the development or exacerbation of depressive and anxiety symptoms. Future research should focus on longitudinal and intervention studies to further explore the causal pathways between malnutrition and psychological disorders. Additionally, the use of standardized assessment tools for both nutrition and mental health would improve comparability across studies and strengthen evidence-based recommendations.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40520-025-03071-y.

Author contributions Conceptualization, A.M., J.G., G.G.; methodology, A.C., A.M., E.BB., J.G., G.G.; formal analysis, A.M.; investigation, A.M., A.C.; resources, A.M.; data curation A.M.; writing—original draft preparation, A.C., A.M. and E.BB.; writing—review and editing, A.M., E.BB., A.C., G.G., J.G., A.W., K.K..; visualization, A.M.; supervision, A.M., E.BB., J.G., G.G., K.K.; project administration, A.M., funding acquisition, A.M. All authors have read and agreed to the published version of the manuscript.

Funding This research was funded by Jagiellonian University statutory resources (N43/DBS/000319; granted to A.M.).

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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