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Review Article

Nutritional Status and Treatment Tolerance in Children Undergoing Leukemia Induction Therapy

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Summary

Nutritional status at diagnosis predicts survival in childhood leukaemia, and the literature disagrees about how much. A large part of that disagreement is not biological: body mass index performs poorly in a child whose weight includes tumour bulk and steroid-driven fluid, and arm measurements detect what it misses.

Objectives: To review the published evidence on nutritional status in children undergoing induction therapy for acute leukaemia: how often malnutrition is present, how it is measured, what it predicts for treatment tolerance and survival, and how status changes across induction itself.

Material and Methods: Narrative review of observational cohorts, retrospective analyses, systematic reviews and nutritional assessment guidance indexed in PubMed and the major haematology, paediatric and nutrition journals. Studies were eligible if they reported the prevalence, measurement or clinical consequences of nutritional status in a defined paediatric acute leukaemia population. No new patient data were generated and no patients were recruited; every estimate quoted is one published by the original investigators.

Results: Reported malnutrition at diagnosis ranges from 0 to 70 per cent across settings, with around 50 per cent in low and middle-income countries, 58.4 per cent in a Mexican cohort and 45.3 per cent classified underweight in an Indian cohort. In the Mexican series, survival differed by body mass index category at 76 against 63 per cent ($p = 0.049$), while relapse differed more sharply by triceps skinfold, at 41 against 12 per cent below and above minus two standard deviations ($p = 0.007$). Stunting carried a hazard ratio for mortality of 6.214 (95% CI 1.372-28.154) and low triceps skinfold 2.91 (95% CI 1.27-6.68), while higher mid-upper arm circumference was protective at 0.85 (95% CI 0.73-1.00). Across induction in a European cohort of 50 children, the proportion with an abnormal body mass index rose from 6 to 20 per cent.

Conclusion: Arm anthropometry outperforms weight-based measures in this population and produces the stronger associations wherever both have been reported. Nutritional status also deteriorates measurably during induction, so a single assessment at diagnosis describes a moving target.

Abbreviations: ALL – Acute Lymphoblastic Leukaemia, AML – Acute Myeloid Leukaemia, BMI – Body Mass Index, MUAC – Mid-Upper Arm Circumference, TSF – Triceps Skinfold Thickness, SD – Standard Deviation, HR – Hazard Ratio, LMIC – Low and Middle-Income Country, HIC – High-Income Country, WHO – World Health Organization, MRD – Minimal Residual Disease, FM – Fat Mass, FFM – Fat-Free Mass.

Keywords: Paediatric Leukaemia; Nutritional Status; Induction Therapy; Anthropometry; Treatment Tolerance

Introduction

Survival in childhood acute leukaemia now exceeds 90 per cent in high-income settings and remains substantially lower elsewhere, and the gap is not explained by disease biology alone [1,2]. Among the host factors proposed to contribute, nutritional status has attracted sustained attention because it is common, measurable and in principle modifiable [3,4].

The World Health Organization defines malnutrition as deficiency, excess or imbalance in energy or nutrient intake, so the term covers undernutrition, overweight and micronutrient deficiency together [5,6]. Both directions matter clinically: undernutrition predominates in low and middle-income countries while overweight predominates in high-income ones, and each has been associated with poorer outcome [3,7,8].

The proposed mechanisms are plausible and multiple. Low body mass and lean tissue impair immune function and increase susceptibility to infection; reduced capacity to metabolise cytotoxic drugs raises the risk of organ toxicity; and recovery is prolonged through extended neutropenia and impaired tissue repair [9,10]. Increased body fat has been linked to the same complications, so fat may play a dual role [9,11].

This review sets out how often malnutrition is present at diagnosis, how it is measured and why that matters, what it predicts for tolerance and survival, and how status changes during induction itself.

Material and Methods

Search strategy: PubMed and the archives of the major haematology, paediatric oncology and clinical nutrition journals were searched for studies of nutritional status in childhood leukaemia. Search terms combined acute leukaemia and paediatric with nutritional status, malnutrition, undernutrition, body mass index, anthropometry, mid-upper arm circumference, treatment tolerance and induction. Reference lists of retrieved cohorts and systematic reviews were screened by hand.

Eligibility: Studies were included if they reported the prevalence, assessment method or clinical consequences of nutritional status in a defined paediatric acute leukaemia population, or evaluated a nutritional intervention in that population. Studies in mixed paediatric cancer cohorts are cited where they address measurement methodology and are identified as such.

Data extraction and handling: Design, cohort size, setting, assessment method, threshold applied and reported outcome estimates were extracted as published. The assessment method is stated alongside every prevalence and outcome figure, because weight-based and arm-based measures classify different children as malnourished and this accounts for much of the variation between studies. No pooling or re-analysis was performed and no patient-level data were obtained. Figures 1 to 4 and Tables 1 to 3 reproduce published values only. This is a narrative synthesis and was not registered as a systematic review.

Results

How common malnutrition is, and why estimates vary: Undernutrition among children and adolescents receiving cancer treatment has been reported across a range from 0 to 70 per cent [12], which is wide enough to require explanation. Around 50 per cent of children with acute lymphoblastic leukaemia in low and middle-income countries are malnourished at diagnosis [4,13], and a Mexican retrospective cohort reported 58.4 per cent (Figure 1) [9].

A prospective Indian study of 64 children and adolescents aged 2 to 20 classified 45.31 per cent as underweight by body mass index,

51.56 per cent as healthy weight and 3.13 per cent as overweight [12]. In high-income settings the balance inverts, with a significant proportion of children with leukaemia categorised as overweight or obese rather than underweight [7,8,14].

Part of the variation is genuinely geographic and part is methodological. Different studies use body mass index, weight for age, arm anthropometry or combinations, applied against different reference standards and thresholds, and these do not identify the same children [3,15,16].

The direction of the association also differs by income setting. A meta-analysis of body mass index and survival in paediatric leukaemia found poorer outcome at both extremes [7], and mortality was elevated in overweight and underweight children with myeloid leukaemia in a large cooperative group analysis [8]. Obesity has been examined separately as a prognostic factor in lymphoblastic disease [11].

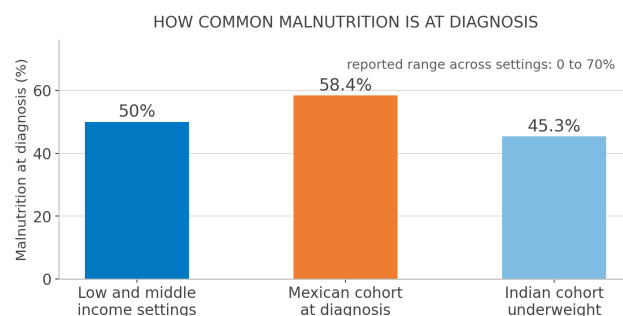


Figure 1: Reported prevalence of malnutrition at diagnosis across settings [4,9,12,13]

The measurement problem: Arm anthropometry provides more accurate information on nutritional status than measures based on body weight in children with cancer [3]. The reason is specific to this population: weight at diagnosis includes tumour bulk, organomegaly and often effusions, and during induction it includes corticosteroid-driven fluid retention and appetite stimulation, none of which reflects nutritional reserve [3,17].

Body composition rather than weight is where the clinically relevant changes appear, specifically the distribution and proportion of fat mass and fat-free mass [4,18]. Mid-upper arm circumference and triceps skinfold thickness sample peripheral soft tissue directly and are less distorted by the disease and its treatment [3,9].

The same cohort can therefore give different answers depending on the instrument, and the Mexican study reported both. Survival differed by body mass index category at 76 against 63 per cent, reaching significance only marginally ($p = 0.049$) (Figure 2) [9]. Relapse differed by triceps skinfold at 41 per cent below minus two standard deviations against 12 per cent above, with $p = 0.007$ (Figure 3) [9].

Body composition studies support the same conclusion from a different direction. Children with cancer differ from healthy peers in the proportion of fat and fat-free mass at a given weight [18], so two children with identical body mass index can differ substantially in lean tissue. Guidance on assessment in this population accordingly recommends measures that sample tissue directly [15,23].

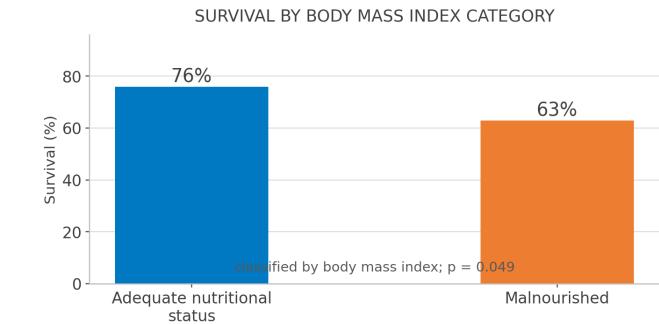


Figure 2: Survival classified by body mass index in a retrospective cohort [9]

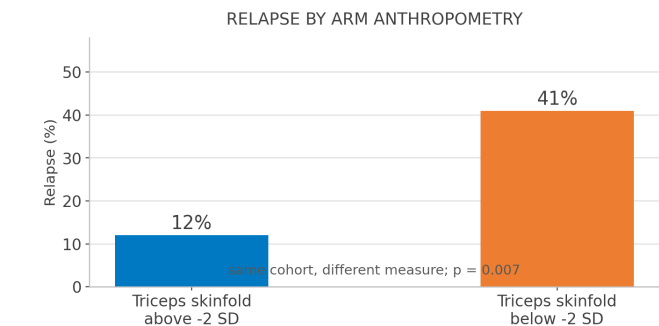


Figure 3: Relapse in the same cohort classified by triceps skinfold thickness [9]

Study	n	Setting	Principal reported finding
Barr et al. 2016 [3]	Review	LMIC focus	Arm anthropometry more accurate than weight-based measures
Rogers et al. [15]	Guidance	International	Assessment tools and screening recommendations
Sharma et al. 2024 [12]	64	India, prospective	45.3% underweight; undernutrition worsens across induction
Petraitiene et al. 2023 [17]	50	Lithuania	Abnormal body mass index rose from 6% to 20%
Mexican cohort 2025 [9]	Retrospective	Mexico	Arm measures outperformed body mass index
Systematic review 2024 [4]	Review	International	Nutritional interventions during treatment assessed

Table 1: Principal studies reviewed, with setting and the finding as reported by the original investigators

What each measure predicts: In multivariable analysis from the same Mexican cohort, stunting carried a hazard ratio for mortality of 6.214 (95% CI 1.372 to 28.154) and triceps skinfold below minus two standard deviations a hazard ratio of 2.91 (95% CI 1.27 to 6.68). Higher mid-upper arm circumference z-score was associated with reduced mortality risk, at 0.85 (95% CI 0.73 to 1.00) [9].

The confidence interval around the stunting estimate is very wide, spanning from 1.4 to 28, which reflects small numbers in that subgroup and should temper any strong reading of the point estimate [9]. The arm measures carry tighter intervals and are the more dependable findings in that analysis.

Malnutrition at diagnosis or during treatment has been linked more broadly to higher infection risk, poorer treatment tolerance and adherence, lower survival and death [4,10,19]. Proposed mediating changes include inflammation, increased energy expenditure, inadequate or excessive caloric intake and altered metabolic pathways [4,18,20].

Status deteriorates during induction: A European observational cohort followed 50 consecutive children with acute lymphoblastic leukaemia through induction using body mass index z-scores against World Health Organization growth standards. The number with an abnormal index rose from 3 (6 per cent) at diagnosis to 10 (20 per cent) at the end of induction, comprising a rise from 2 to 6 in the overweight or obese category and from 1 to 4 in the underweight category (Figure 4) [17].

At the end of induction, all children categorised as overweight or obese were aged between 0 and 5 years [17], which points toward

corticosteroid effect in the youngest patients rather than a change in habitual intake. The prospective Indian study found a parallel trend of worsening undernutrition in both underweight and healthy weight groups across the four weeks of induction [12].

Deterioration in both directions during a four-week block has a practical implication. A single assessment at diagnosis, which is what most cohorts report, describes a status that will have changed by the time treatment decisions dependent on it are taken [12,17].

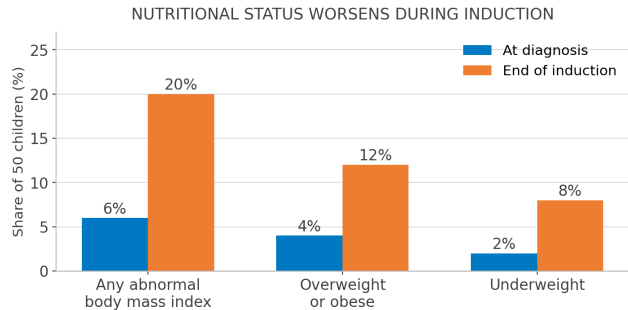


Figure 4: Change in nutritional status across induction in 50 children [17]

Measure	What it captures	Performance in this population
Body mass index	Total weight for height	Distorted by tumour bulk and steroid fluid [3,17]
Weight for age	Total weight	Same distortion; no height adjustment [3]
Mid-upper arm circumference	Peripheral muscle and fat	Protective association, HR 0.85 [3,9]
Triceps skinfold	Subcutaneous fat store	Strongest relapse association, p = 0.007 [9]
Stunting (height for age)	Chronic undernutrition	Large effect, very wide interval [9]

Table 2: Assessment measures and how each behaves in children receiving leukaemia therapy

What intervention achieves: Nutritional status is potentially modifiable, which distinguishes it from most prognostic factors in this disease, and interventions have been reviewed systematically [4]. Relationships between status and outcome are described as subject to change with nutritional intervention [3], though demonstrating that a specific intervention alters survival is a different and harder claim.

Reduced oral intake during induction has identifiable causes: nausea, vomiting, diarrhoea, mucositis and renal losses all follow from the regimen itself [4,20,21]. These are treatable, and addressing them is supportive care rather than nutritional therapy, which may be why intervention trials have been difficult to design cleanly [4,15].

Weight extremes over time rather than at a point: Analyses using duration of weight extremes rather than a single classification have

reported effects on both survival and toxicity, which is a different and arguably better-specified exposure than status at diagnosis [26]. Being underweight and losing weight during therapy each carried adverse weight in a large European cohort [27].

Prospective observation across whole treatment courses shows status changing repeatedly rather than settling [25], and multicentre work following patients from diagnosis through therapy found malnutrition appearing in children who began adequately nourished [14]. Narrative and systematic reviews of assessment have set out how these trajectories should be captured [22,23].

The infection link: The mechanism most often invoked is impaired immunity, and the clinical consequence has been measured. Malnutrition in childhood cancer has been associated specifically with infection and mortality [24], and in a Nicaraguan cohort with treatment-related morbidity as well as survival [28].

That places nutritional status alongside the other determinants of infectious risk during induction, where antibacterial prophylaxis and supportive care standards have their own evidence base [29,30]. Whether nutritional intervention reduces infection independently of those measures has not been established, and separating the two would require a trial designed for the purpose [4,24].

Exposure definition	Reported association	Source
Status at diagnosis	Survival and relapse	Retrospective cohorts [9,14]
Duration of weight extremes	Survival and toxicity	Trial cohort analysis [26]
Weight loss during therapy	Reduced survival	European cohort [27]
Change across induction	Not yet linked to outcome	Small prospective cohorts [12,17]

Table 3: How the exposure has been defined across studies and what each definition predicts

Discussion

The association between nutritional status and outcome in childhood leukaemia is real but reported inconsistently, and the inconsistency has a specific and largely methodological source. Weight-based measures perform poorly here because weight at diagnosis contains tumour, and weight during induction contains corticosteroid-driven fluid [3,17]. Neither reflects nutritional reserve.

Where both instruments have been applied to one cohort, the arm measures produced the stronger and more precise associations: relapse at 41 against 12 per cent by triceps skinfold with p = 0.007, against survival at 76 versus 63 per cent by body mass index with p = 0.049 [9]. That is the clearest available evidence that the choice of instrument, not the underlying biology, drives much of the disagreement in this field.

Why a single assessment is insufficient

Nutritional status is not a baseline characteristic in this setting; it is a variable that moves under treatment. Abnormal body mass index tripled across a single induction block, in both directions [17], and undernutrition worsened across four weeks in a separate prospective cohort including children who began at healthy weight [12].

Studies reporting status only at diagnosis are therefore relating outcome to a measurement that no longer describes the patient by the time complications occur. Serial assessment through induction would be straightforward with arm anthropometry, which requires a tape measure and calipers rather than any equipment a ward would lack [3,15].

The two directions of malnutrition

Undernutrition and overweight are grouped under one definition and are often analysed as one exposure, but their mechanisms differ [5,7]. Undernutrition plausibly impairs immune function and drug metabolism [9,10]; overweight has been linked to altered pharmacokinetics and to the same complications by a different route, so body fat may act in both directions [9,11].

Analysing them together as abnormal status risks cancelling opposing effects. The finding that all overweight children at the end of induction were aged under five [17] further suggests that the overweight category in this setting partly reflects treatment rather than habitual nutrition, which is a different exposure again.

Study limitations

The limitations belong to the underlying literature. Cohorts are small, with the studies reporting serial change enrolling 50 and 64 children respectively [12,17]. Assessment methods, reference standards and thresholds differ between studies and classify different children as malnourished, which accounts for much of the reported prevalence range [3,15,16]. Confidence intervals around several effect estimates are very wide, notably for stunting [9]. Nutritional status correlates with socioeconomic circumstance, healthcare access and treatment abandonment, so residual confounding is substantial in observational designs [3,13]. And most analyses relate outcome to status at diagnosis alone, despite evidence that status changes materially within weeks [12,17].

Two gaps deserve naming. No trial has tested whether correcting nutritional status during induction alters treatment tolerance or survival, so the modifiability that makes this factor attractive remains an inference [3,4]. And no study reviewed here reports outcomes stratified by both direction of malnutrition and assessment method, which is what would separate the measurement problem from the biological one [9,15].

Conclusion

Malnutrition is present at diagnosis in around half of children with acute leukaemia in low and middle-income settings, with reported estimates spanning 0 to 70 per cent across the literature. It predicts survival, relapse and treatment tolerance, but the strength of that prediction depends heavily on how status is measured. In the one cohort reporting both, triceps skinfold separated relapse at 41 against 12 per cent while body mass index separated survival at 76 against 63 per cent only marginally, and mid-upper arm circumference was independently protective. Arm anthropometry outperforms weight-based assessment because weight in this population contains tumour and corticosteroid-driven fluid rather than nutritional reserve. Status also worsens measurably within a single induction block, in both directions, so assessment at diagnosis alone describes a patient who has already changed.

Two changes follow that need no new evidence. Reporting mid-upper arm circumference and triceps skinfold alongside body mass index would let future analyses be compared, which at present they largely cannot be [3,15,23]. And repeating the assessment at the end of induction rather than at diagnosis alone would capture a change that occurs in one child in five [17].

The question that does need a trial is whether correcting status alters outcome. Nutritional status is among the few prognostic factors in this disease that is modifiable, which is what makes it interesting, and that modifiability remains an inference rather than a demonstrated result [3,4].

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Conflict of Interest

The authors declare no competing interests.

Ethics Statement

This article reviews previously published studies only. No new patient data were collected and no participants were recruited, so ethical approval was not required.

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