Adult malnutrition, nutritional interventions and outcomes in Singapore: a scoping review of local studies for the past 20 years

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Abstract
Background: There is currently no review published on the prevalence and incidence of malnutrition in Singapore across various populations, or what interventions or policies are in place for preventing/treating malnutrition.
Objectives: This review aims to determine: (a) incidence and prevalence of malnutrition in the community, and in acute, intermediate and long-term care facilities; (b) interventions implemented for screening, assessing and treating/preventing malnutrition; (c) specific clinical populations investigated for malnutrition or nutritional therapy; and (d) implications of malnutrition and effectiveness of treating malnutrition or using nutritional therapy in Singapore.
Methods: A structured search strategy was applied to available electronic databases (MEDLINE/PubMed, EMBASE, CINAHL, the Cochrane Library and Google Scholar) using selected search terms, with additional reports and grey literature identified using iterative searches.
Results: Forty-two articles were found, with the majority of research performed in the community and acute care settings. Malnutrition screening and assessment is the most common nutritional research performed in Singapore. Approximately 14.7% to 65.0% of acute care and 2.8% to 31.5% of community populations are found to be malnourished. Limited interventional and economic-related studies are available.
Conclusion: Malnutrition rates in Singapore appear to be similar to other developed countries. Future studies will need to focus on nutritional intervention, cost-effectiveness analyses and specific populations such as the underprivileged, chronically ill and those dependent on nutritional support.

Keywords
Malnutrition, Singapore, Nutrition Support

Introduction
Malnutrition is associated with increased mortality and morbidity. Higher hospitalisation and general practitioner utilisation rates have been reported for malnourished populations as well, leading to increased healthcare and societal costs.1 Internationally, the prevalence of protein–energy malnutrition ranges from 0.8% to 24.6%.2 A consensus scheme for malnutrition diagnosis was recently reported, in which two criteria – one phenotypic (non-volitional weight loss, low body mass index (BMI) and reduced muscle mass) and one aetiological criterion (reduced food intake or assimilation and disease burden/inflammation) were required for diagnosis.3

There is currently no review published on the prevalence and incidence of malnutrition in Singapore, or what interventions or policies are in place for preventing/treating malnutrition. Although costs and effects of malnutrition have been widely described in the literature worldwide, the economic and clinical implications of malnutrition in the

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local Singapore population is unclear, which led to the conceptualisation and implementation of this scoping review. This scoping review was conducted to map the research completed systematically and to identify any existing gaps in knowledge in Singapore’s clinical nutrition research field. It aims to determine the: (a) incidence and prevalence of malnutrition in community-dwelling residents and patients in acute, intermediate and long-term care (ILTC) facilities; (b) interventions implemented for screening, assessing and treating/preventing malnutrition; (c) specific clinical populations that are investigated for malnutrition or nutritional therapy; (d) effectiveness of treating malnutrition using nutritional therapy; and (e) implications (clinical and cost) of malnutrition in Singapore.

**Methods**

A structured search strategy was applied to MEDLINE/PubMed, EMBASE, CINAHL, the Cochrane Library and Google Scholar, using combinations of the following terms as shown in the Supplementary Appendix, and bibliographies of articles. Grey literature from iterative searches was also performed to provide a complete view of information.

There was no restriction on language and the control groups used in the studies. Inclusion criteria included: (a) Singaporean adult aged 18 years or over; (b) receiving care in the community, acute or ILTC settings; (c) receiving nutritional therapy (enteral nutrition (EN), parenteral nutrition (PN) or oral nutritional supplements (ONSs)) or screened/assessed for nutritional status; and (d) published studies in the past 20 years from 1 January 2000 to 31 December 2019.

Only data related to the adult population were used from studies that included mixed populations (paediatrics and adult). Randomised controlled trials, non-randomised interventional studies and observational studies that reported nutritional outcomes (such as nutritional status, anthropometric measurements and nutrition-related biochemistry) were included. Case reports, letters to editors, expert opinions, conference proceedings, clinical/interventional studies on healthy participants, validation studies of non-nutritional-related tools and studies without any relevant nutritional outcomes were excluded.

The protocol was drafted using the preferred reporting items for systematic reviews and meta-analysis (PRISMA) protocols, available on request from the corresponding author, and the review is written in accordance with the PRISMA extension for scoping reviews (ScR) checklist1 (see Supplementary Appendix).

The title, abstract and keywords of the articles were screened for relevance by two assessors (AW and YX). Duplicates and studies that did not provide relevant information were excluded. Screened articles were retrieved for full-text reading and checked for relevance. Any discrepancies were resolved by consensus. If no agreement was reached, a third reviewer’s (JD) opinion was sought.

AW and YX extracted data with a piloted form and JD checked the data obtained. The extracted data were categorised into: (a) author and publication year; (b) population size and characteristics; (c) type of study and design; (d) the intervention examined; (e) study time frame/duration; (f) prevalence/incidence of malnutrition or risk of malnutrition; and (g) clinical, social or cost outcomes. After extraction, the data were analysed and summarised into a summary format based on the study populations.

**Results**

A flow diagram of the search results is shown in Figure 1. A total of 1873 records was retrieved from the database search, with 382 duplicates and 1440 articles excluded after title/abstract screening. Fifty-one articles were left for full-text screening, and nine were excluded secondary to reasons, as shown in Figure 1. A summary of the studies is presented in Tables 1 to 5.

There were 13 studies performed in community populations5–17 (Table 1), 21 studies in acute care18–38 (Table 2), which includes six (n=6) in critical care (intensive care unit (ICU))33–38 settings (Table 3), three (n=3) in long-term care settings39–41 (Table 4) and five (n=5) in outpatient settings42–46 (Table 5). Sixteen (n=16) studies were specific to the geriatric population,5, 6, 8–16, 25, 41, 42, 44, 46 while the rest were on the general adult populations.7, 18–24, 26–30, 32–41, 43, 45 Eight (n=8) studies were published between 2000 and 2009,17–19, 26, 27, 41, 43, 45 and the remainder (n=34) from 2010 to 2019,5–16, 20–25, 28–40, 42, 44, 46.

Twelve (n=12) studies involved or investigated the use of EN and/or PN,18, 22, 26, 28, 30–33, 35, 37, 38, 40 while the rest (n=32) involved nutritional screening and/or assessment.5–17, 19–21, 23–25, 27, 29, 34, 36, 39, 41–46

Only two (n=2) studies were randomised controlled trials,26, 30 and the rest were retrospective,18, 28, 31, 32, 41, 43, 46 (n=7), prospective or cross-sectional5–8, 10–17, 19–21, 23–25, 27, 29, 33–40, 42, 44, 45 (n=31), pre-post22 (n=1) and validation9 (n=1) studies. Nine (n=9) studies belong to the Singapore Longitudinal Ageing Studies 1 and 2 population,5, 6, 8, 9, 13–17

Five (n=5) studies reported economic outcomes but were not cost-effectiveness trials,20, 23, 27, 31, 40

**Nutritional screening and assessment**

The majority of the studies used validated screening and assessment tools, which were described in other reviews,47–50 and thus will not be described in detail in this review.

In the community population (Table 1), the mini nutritional assessment short-form (MNA-SF)51, 52 (eight of 11 studies, 72.8%)6, 8, 9, 12–16 and the NSI determine your nutritional health checklist53 (seven of 11 studies, 63.6%) were the tools of choice for screening.5–7, 13, 14, 16, 17 Some studies used multiple screening tools (five of 11 studies, 45.5%).6, 9, 13, 14, 16 One study6 used the geriatric nutritional risk index54 and ESPEN diagnostic criteria for malnutrition55 for nutritional screening. The mini nutritional assessment (MNA) was found to be the tool of choice for nutritional assessment56 (three of three studies, 100%).7, 10, 11

For inpatient acute care (Table 2), the locally designed 3-minute nutrition screening (3MinNS) is the most frequently reported tool (three of seven studies, 43%).19, 21, 23

One study45 used four tools — Tan Tock Seng Hospital nutritional screening tool, nutrition risk screening 2002 (NRS 2002),57 MNA-SF and short nutritional assessment questionnaire (SNAQ).58 The malnutrition screening tool (MST)59 was...
reported in one study,\textsuperscript{27} while two studies used BMI as a surrogate for nutritional screening.\textsuperscript{18, 26} The preferred nutritional assessment tool was the subjective global assessment (SGA)\textsuperscript{60} (seven of nine studies, 77.7%),\textsuperscript{19–21, 25, 27, 29, 30} 7-point subjective global assessment (SGA 7-point)\textsuperscript{61} (two of nine studies, 22.2%)\textsuperscript{22, 24} and MNA (one of nine studies).\textsuperscript{25}

All ICU studies reported using the modified nutrition risk in critically ill (mNUTRIC) score (Table 3).\textsuperscript{33–38} The mNUTRIC determines which ICU patients are more likely to benefit from nutrition support.\textsuperscript{62} However, it does not contain any components of nutritional assessment, such as physical or dietary assessment. The recent ESPEN guidelines for critical care nutrition also disagree with its use as a nutritional screening tool in the ICU.\textsuperscript{63} All studies\textsuperscript{35, 36} used the SGA 7-point, which is an expansion of the traditional 3-point SGA.\textsuperscript{61}

In the outpatient settings (Table 5), BMI was used as a screening tool (two of five studies, 40%)\textsuperscript{43, 45} in the earlier years while the NSI (three of five studies, 40%) was used more recently.\textsuperscript{42, 44, 46} One study used a daily protein intake of less than 0.8 g/kg/day and albumin level as an indicator for malnutrition.\textsuperscript{45} No assessment tools were used in the outpatient setting. Finally, in long-term care (Table 4), only one study used a validated nutritional assessment tool (MNA).\textsuperscript{39} An older study used clinical impression as a surrogate of nutritional assessment.\textsuperscript{41}

Prevalence and incidence of malnutrition in Singapore

Malnutrition in acute care. National prevalence data in Singapore are limited. The majority of the studies in acute settings (non-critical care) found the prevalence to be 14.7–65.0% in various patient populations.\textsuperscript{15, 20, 25, 27, 29, 30} For specific inpatient populations, Lim\textsuperscript{25} reported 35% of elderly patients to be malnourished, and Wong et al.\textsuperscript{30} reported a 65% prevalence of malnutrition in patients (n=23) with moderate to severe pressure injuries.

In the ICU setting, Lew and colleagues\textsuperscript{35, 36} reported 28% of patients in a mixed-speciality ICU were malnourished using the SGA. Other ICU studies\textsuperscript{33, 34} reported 45.4% of the surgical ICU population with high mNUTRIC scores but not malnutrition risk or prevalence.

Malnutrition in step-down and long-term care. ILTC in Singapore is predominantly carried out in community hospitals and nursing homes. No studies reported on malnutrition prevalence rates in community hospitals. There are also minimal studies published examining the nutritional status of nursing home residents. In a paper published in 2003, 22% of residents appeared undernourished, but the nutritional assessment was performed based on clinical impression.\textsuperscript{41} A newer study used MNA and reported a 39% malnutrition prevalence in a nursing home.\textsuperscript{39}

Malnutrition in community and outpatient settings. The Singapore Longitudinal Ageing Study 1 (SLAS-1) (n=2804) and 2 (SLAS-2) (n=3241) are cross-sectional studies of community-dwelling adults.\textsuperscript{6, 13} Using the MNA-SF, the authors identified a malnutrition prevalence of 2.4% and malnutrition risk of 26.8% in the population. When a validated nutritional assessment tool (MNA) was used, the malnutrition prevalence in the community ranged from 2.8% to 31.5%.\textsuperscript{6, 11, 14, 15}
Table 1. Nutritional studies on populations residing in the community.

| Author, year | Study type | Population | & site | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|-------------|------------|------------|--------|-------------|------------------|-------------------------------|-----------------|
| Cheong et al. 2020 | Population-based longitudinal | Community-dwelling older adults aged >55 years from SLAS-2 study N=1297 | | Identifying baseline risk factors (demographic, socioeconomic, medical, psychological factors and biochemical markers) and incident of frailty at baseline and follow up in 3 to 5 years | S: NSI | P: 12.5% at follow-up 17.2% (frail) 11.6% (not frail) | 1) Individual nutritionally at risk X 1.5 times more likely to develop frailty (OR 1.58, 95% CI 1.03–2.37, P=0.033) |
| Chye et al. 2018 | Cross-sectional | Community-dwelling older adults aged >55 years from SLAS-1 and SLAS-2 studies N=9541 | | Data collected from the Singapore Longitudinal Aging Studies | S: MNA-SF, NSI | R: NSI 24.7% (moderate) 63% (high) MNA-SF 26.8% P: MNA-SF 2.4% | 1) Prevalence of malnutrition was lowest among robust and normal cognition individuals and highest among frail and cognitively impaired 2) Pre-frailty and cognitively impaired individuals vs. robust cognitive normal associated with the highest odds ratio (OR 8.16, P<0.001) |
| Koo et al. 2014 | Cross-sectional | Community-dwelling and nursing home public assistance recipients aged >55 years in central Singapore district N=465 | | In-depth interviews conducted on malnourished individuals to understand the barriers to achieving adequate nutrition | S: NSI | A: MNA | 1) Independent factors for risk of malnutrition for community-dwelling group: a) Advanced age (OR 1.64, 95% CI 1.04–2.60, P=0.034) b) Unmarried (OR 2.43, 95% CI 1.17–5.01, P=0.017) c) BADL impairment (OR 2.20, 95% CI 1.30–3.70, P<0.003) d) Risk of depression (ad OR 2.66, 95% CI 1.46–4.83, P<0.001) e) BMI <19 (OR 9.71, 95% CI 3.46–17.2, P<0.001) |
| Lu et al. 2019 | Cross-sectional | Community-dwelling older adults aged >55 years from SLAS-2 study N=189 | | Data collected from the Singapore Longitudinal Aging Studies (SLAS-2), association of nutritional and metabolic biomarkers (essential amino acids, vitamins, nicotine-derived metabolites and peripheral blood mononuclear cells) with the presence of sarcopenia were estimated using logistic regressions | S: MNA-SF | P: MNA-SF 2.8% (community-dwelling) 1.5% (nursing home) R: MNA 30.4% (community) 68.2% (nursing home) NSI 67.7% (community) 45.5% (nursing home) | 1) Sarcopenia was associated with lower MNA score (P<0.001) 2) Sarcopenic elderly have lower BMI and leptin, and higher adiponectin and high-density lipoproteins (P<0.001) 3) MNA score (P<0.001) was positively associated with ASMI 4) Risk of malnutrition (P<0.001) was negatively associated with ASMI |
| Ng et al. 2017 | Validation | Community-dwelling older adults aged >55 years from SLAS-1 study Development stage N=1550 Validation stage N=924 | | Data collected from the Singapore Longitudinal Aging Studies (SLAS), developed and evaluated against GNRI/MNA, ESPEN-M, and calibrated in a validation cohort, for a nutritional prognostic index that predicts future mortality risk among community living older persons | S: MNA-SF, GNRI, ESPEN operational definition of malnutrition | P: MNA-SF 1.8% (malnourished) ESPEN 1.8% (malnourished) R: GNRI 85% (no risk) 10% (low risk) 4% (moderate risk) 0% (major risk) MNA-SF 24.1% (at risk) | 1) ENIGMA component indicators and risk score were independently associated with significantly increased mortality HR after adjustment 2) ENIGMA also showed better discriminatory accuracy than MNA-SF, GNRI, and ESPEN-M in predicting long-term mortality risks |
| Tay et al. 2015 | Cross-sectional | Community-dwelling older adults aged >50 years N=200 | | Assessment of comorbidities, cognitive and functional performance, physical activity, nutritional status, grip strength and biochemical parameters, and comparing sarcopenic vs. non-sarcopenic subjects | A: MNA | P: 0% R: All (7%) 14% (sarcopenic) 47% (non-sarcopenic) | 1) Malnutrition results in higher odds for sarcopenia in women (OR 5.71, 95% CI 1.13–28.84, P=0.035) 2) Sarcopenic subjects more likely at risk of malnutrition (14% vs. 4.7%, P<0.0025) |
| Tay et al. 2018 | Cross-sectional | Community-dwelling older adults with mild cognitive impairment and mild-to-moderate Alzheimer's disease aged >55 years N=129 | | Measurement of cognitive, functional and physical performance, physical activity level, nutritional status and blood biomarkers and to determine what factors are associated with pre-sarcopenia and sarcopenia | A: MNA | P: 73.4% (non-sarcopenic) 42.9% (pre-sarcopenia) 47.2% (sarcopenia) 31.5% (all) | 1) Malnutrition independently increased risk for a) Pre-sarcopenia (RR 7.53, 95% CI 1.20–47.51, P=0.032) b) Sarcopenia (RR 1.19, 95% CI 2.85–49.77, P=0.001) 2) A combined pro-inflammatory and endocrine-deficient state increased the risk of sarcopenia (RR 5.17, 95% CI 1.31–20.37, P=0.019) |
| Tay et al. 2019 | Prospective cohort | Community-dwelling older adults aged >55 years N=135 | | Community-based programme with multidomain geriatric screen and physical fitness assessment, to distinguish between frail/pre-frail from robust elderly adults | S: MNA-SF | P: 4.4% (aggregated 1% (robust) 13.9% (pre-frail/frail) R: 20.7% (aggregated 12.1% (robust) 44.4% (pre-frail/frail) | 1) Pre-frailty/frailty was independently associated with a) Depression (OR 2.90, 95% CI 1.05–7.90, P=0.040) b) Malnutrition (OR 6.07, 95% CI 2.52–14.64, P<0.001) |

(Continued)
Table 1. (Continued)

| Author, year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|--------------|------------|-------------------|--------------|------------------------------------------|----------------------------------------|--------------|
| Wei et al.13 | Cross-sectional | Community-dwelling older adults aged ≥55 years from SLAS-1 and SLAS-2 studies N=605 | Nutritional status, physical frailty phenotype data were collected. Multinomial logistic regression was used to calculate the odds ratio (OR) between each risk factor and the risk of prefrailty/frailty. | S: MNA-SF, NSI | P: MNA-SF 2.7% R: MNA-SF 27.6% | 1) MNA-at-risk malnutrition was associated with: a) Prefrailty (OR 2.11 and 6.71) b) Frailty (OR 2.72 and 17.4) 2) OR was lower with NSI moderate and high nutritional risk for: a) Prefrailty (OR 1.39 and 1.76) b) Frailty (OR 1.27 and 1.93) |
| Wei et al. (a)15 | Population-based longitudinal | Community-dwelling older adults aged ≥55 years from SLAS-2 study N=162 | Nutritional status, physical frailty phenotype data were collected at both baseline and follow-up. Multinomial logistic regression was used to estimate odds ratios (ORs) of associations | S: MNA-SF | R: 20.2% (no distinction made between at-risk and malnourished groups) | 1) Being at risk of malnutrition/malnourished was associated with increased OR for: a) Prefrailty (OR 2.76, 95% CI 1.86–4.10) b) Frailty (OR 4.10, 95% CI 1.41–11.9) 2) Individuals who were robust at baseline but persistently at risk of malnutrition/malnourished had increased odds of conversion to prefrail/frail on follow-up (OR 3.45, 95% CI 1.00–11.9) |
| Wei et al. (b)14 | Population-based longitudinal | Community-dwelling older adults aged ≥55 years from SLAS-1 study N=2804 | Baseline data of physical frailty and nutritional status used and assessed for associations with adverse health outcomes (functional dependency and poor QOL) | S: MNA-SF, NSI | P: MNA-SF 3.9% R: MNA-SF 31.4% | 1) Robust individuals with normal nutritional vs. prefrail/frail individuals with malnourished had increased odds of conversion to pre-frail/frail on follow-up (OR 3.22, 95% CI 1.13–9.16) 2) Improvement in nutritional status was associated with decreased incident of mortality (HR 0.43, 95% CI 0.23–0.80) |
| Wei et al.16 | Population-based longitudinal | Community-dwelling older adults aged ≥55 years from SLAS-1 study N=2075 | Nutritional status, IADLs/ADLs and QOL were assessed at both baseline and at the 4.5 year follow-up. Estimates of associations between changes in nutritional status and adverse health outcomes were analysed | S: MNA-SF, NSI | P: MNA-SF 4.4% (baseline) 3.1% (follow-up) R: MNA-SF 32.6% (baseline) 30.1% (follow-up) NSI: 25.7% (baseline, moderate risk) 4.7% (high risk) | 1) Nutritional deterioration was associated with increased incident of: a) IADL/ADL disability (OR 3.22, 95% CI 1.13–9.16) b) poor QOL (OR 4.53, 95% CI 2.13–9.64) c) mortality (HR 4.76, 95% CI 2.12–8.03) 2) Improvement in nutritional status was associated with decreased incident of IADL/ADL disability (OR 0.17, 95% CI 0.05–0.59) 3) Persistent poor nutrition was associated with increased incidence of: a) Poor QOL (OR 1.92, 95% CI 1.05–3.52) b) mortality (HR 2.57, 95% CI 1.59–4.15) 4) Improvement in nutritional status was associated with decreased incidence of mortality (HR 0.43, 95% CI 0.23–0.80) |
| Yap et al.17 | Prospective cohort survey | Community-dwelling older adults from SLAS-1 study N=2605 | Nutritional survey performed via door-to-door census surveys | S: NSI | P: NSI 25.5% (moderate risk) 46% (high risk) | 1) Factors associated with nutritional risks include: a) Male gender (OR 1.29, 95% CI 1.05–1.57) b) Lower-end housing (OR 1.41, 95% CI 0.97–2.05) c) Being single, divorced or widowed (OR 1.46, 95% CI 1.15–1.84) d) Living alone (OR 2.06, 95% CI 1.43–2.94) 2) Individuals at nutritional risk were more likely to have: a) ≥3 comorbid medical conditions (multivariate OR 3.14, 95% CI 2.11–4.69) b) Hospitalised (OR 2.24, 95% CI 1.49–3.36) c) Functionally dependent for ≥1 instrumental or basic activities of daily living (OR 1.72, 95% CI 1.41–2.11) d) Poor or fair self-rated health (OR 2.29, 95% CI 1.91–2.78) e) Lowest tertile SF-12 quality of life scores (OR 2.01, 95% CI 1.67–2.42) f) Depression (OR 1.81, 95% CI 1.42–2.31) |

ADL: activities of daily living; ASMI: appendicular skeletal muscle index; BADL: basic activities of daily living; BMI: body mass index; CI: confidence interval; CRP: C-reactive protein; DRG: diagnosis-related group; EQ-5D VAS: EQ-5D visual analogue scale; GNRI: geriatric nutritional risk index; HR: hazard ratio; IADL: instrumental activities of daily living; LOS: length of stay; MNA: mini nutrition assessment; MNA-SF: mini nutrition assessment short form; NSI: nutrition screening initiative DETERMINE checklist; OR: odds ratio; QOL: quality of life; SGA: subjective global assessment; SF-12: 12-item short form survey.
Table 2. Nutritional studies on patients in acute hospital settings.

| Author; year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|--------------|------------|-------------------|--------------|------------------------------------------|----------------------------------------|---------------|
| Chong and Vu18 2006 | Retrospective observational | Inpatient adults on PEG aged 17–94 years N=106 | Demographics, clinical and biochemical variables before PEG placements were analysed. Patients were followed up in outpatient clinic at 6-monthly intervals. Multiple logistic regression was used to predict outcomes | S: BMI <20 R: 43% (assumed malnourished) | 1) Predictors of mortality:  
   a) Older age (OR 1.05, 95% CI 1.007–1.107, P=0.023)  
   b) Abnormal nutritional status based on BMI <20 kg/m² (OR 0.074, 95% CI 0.016–0.348, P=0.001) |  |
| Lim25 2010 | Cross-sectional | Inpatient geriatric adults aged ≥60 years N=281 | Patients were screened within 72 hours of admission using 4 screening tools. Nutrition status was assessed by single dietitian using four malnutrition assessment methods and reassessed for weight and arm anthropometry on discharge. Demographics, appetite, swallowing, clinical outcomes were collected. Regression analysis was used to determine association between the nutritional assessment indices and clinical outcomes | A: SGA, MNA  
   B: TTSH-NST, NRS  
   C: CAMA (Male 21.4cm², Female 25.4cm²),  
   D: SNAQ 6% | 1) Malnourished vs. well-nourished:  
   a) Swallowing impairment (20% vs. 5%, P<0.001)  
   b) Poor appetite (77% vs. 24%, P<0.001)  
   c) Dementia (44% vs. 28%, P=0.005)  
   d) Depression (34% vs. 22%, P=0.041)  
   e) Poor functional status (MBI 48.3±29.8 vs. 65.1±25.4, P<0.001)  
   f) Malnourished more likely to be discharged to higher level care (adjusted OR 2.46, 95% CI 1.27–4.70, P<0.05)  
   g) Malnourished poorer outcomes – prevalence of increased LOS 45% higher (P<0.009), 3-month readmission rates 75% higher (P=0.001), 6-month mortality rates 3.5 times higher (P<0.001), and 6-month functional score 40% lower (P<0.001) |  |
| Lim et al.19 2009 | Prospective cohort | Inpatient adults aged 18–74 years N=818 | Patients were screened using five indicators of malnutrition risk (unintentional weight loss in 6 months, muscle wasting in the temporalis and clavicular areas) with a new screening tool. The same patients were assessed using the reference standard, SGA, within 48 hours. Sensitivity, specificity and the best cut-off scores were determined. Positive predictive value (PPV) and negative predictive value (NPV) for the individual parameters and possible combinations were determined | A: SGA  
   B: 3 MinNS  
   C: SNAQ 6% | 1) Optimal cut-off score for 3-MinNS to identify:  
   a) At risk of malnutrition 3 (sensitivity 86% and specificity 83%)  
   b) Severely malnourished 5 (sensitivity 93% and specificity 86%) |  |
| Lim et al.20 2012 | Prospective cohort with a matched case control | Inpatient adults aged 18–74 years N=818 | Nutrition status of adults patients admitted was assessed within 48 hours of admission using SGA, LOS, hospitalisation cost, inpatient mortality and unplanned readmission were collected over 3 years. DRGs were matched to confirm the effect of malnutrition on LOS and cost, versus well-nourished patients with a similar disease. Statistical analyses performed to determine differences in LOS and hospitalisation costs between well-nourished and malnourished groups and the association between nutritional status and mortality/readmission | A: SGA | 1) Malnourished vs. well-nourished patients:  
   a) Longer hospital stays (6.9±5.7 days vs. 4.6±5.6 days, P<0.001)  
   b) More likely to be readmitted within 15 days (adjusted RR 1.9, 95% CI 1.1–3.2, P<0.025)  
   c) Hospitalised longer (45% vs. 21%, P<0.001)  
   d) Higher mortality at 1 year (34% vs. 4.1%, 2 years (42.6% vs. 6.7%) and 3 years (48.5% vs. 9.9%) (P<0.001 for all)  
   e) Higher hospitalisation cost ($34,661 ± $6,666 vs. $33,707 ± $5,441, P<0.085)  
   f) Greater mean difference between actual cost of hospitalisation and average cost within a DRG ($392±6,530 vs. $348±3,994, P<0.014) | 2) Positive predictive value (PPV) 67% and negative predictive value (NPV) 94% using cut-off score 3 when compared with SGA |  |
| Lim et al. (a)21 2013 | Pre-post cohort | Malnourished adult patients discharged from a tertiary hospital aged ≥18 years N=26 | Patients received inpatient nutrition intervention and outpatient follow-up for the pre-cohort. For the post-cohort, ambulatory nutrition support for 4 months was initiated to provide telephone follow-up and home visits or outpatient clinic. SGA, weight, EQ-SDV, handgrip strength were measured at baseline and 5 months post-discharge. Pre- and post-intervention results were compared | A: SGA 7 point | 1) Mean weight increased from 440 ± 8.5 kg to 463 ± 9.6 kg (P<0.001)  
   2) EQ-SDV increased from 61.2 ± 19.8 to 71.6 ± 17.4 (P<0.001)  
   3) Handgrip strength increased from 15.1 ± 7.1 kg force to 17.5 ± 8.5 kg force (P<0.001)  
   4) 73.8% of patients with improvement in SGA |  |

(Continued)
| Author, year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|-------------|------------|-------------------|--------------|---------------------------------|---------------------------------|----------------|
| Lim et al. (b) 2013 | Cross-sectional | Inpatient adults in surgical and oncology wards aged ≥21 years N=121 | Patients were screened within 24 hours of admission by nurses, and assessed by dietitian using SGA within 48 hours of admission. The sensitivity, specificity, best cut-off score, and interrater reliability for 3-MinNS were determined | S: 3Min-NS A: SGA | P: SGA 46% | 1) Best 3-MinNS cut-off score to identify all patients at risk of malnutrition (39% sensitivity, 88% specificity; AUC 0.89, P<0.001). The same score identified all severely malnourished (100% sensitivity, AUC 0.92, P<0.001) 2) Strong correlation between 3-MinNS and SGA (r=0.78, P<0.001). Agreement between 2 nurses conducting 3-MinNS was 78% (κ=0.58, P<0.001) |
| Lim et al. 2014 | Prospective cohort | Inpatient adults aged 18–74 years N=818 | Patients were screened for risk of malnutrition within 24 hours of admission. Nutritional parameters, LOS, readmission, hospitalisation cost, mortality data and DRG were collected. Nutritional parameters between at risk and not at risk of malnutrition patients were compared. Statistical analyses were performed to determine differences in LOS and cost of hospitalisation between malnutrition vs. no malnutrition risk patients, and to determine if malnutrition risk was associated with readmission and mortality | S: 3Min-NS A: SGA | P: 93% (moderate) R: 37% | 1) Patients at risk of malnutrition vs. not at risk: a) Older, lower body weight, BMI, mid-arm anthropometrics and albumin levels (all P<0.001) b) Positive association with longer LOS (6.6±7.1 days vs. 4.5±5.5 days, P=0.001) c) Increased mortality rate at 1 year (27.8% vs. 3.9%), 2 years (33.8% vs. 7.2%) and 3 years (39.1% vs. 10.5%) (P<0.001 for all) d) Higher mean hospitalisation cost (S$4540±4961 vs. S$3630±4691, P<0.001) e) Mean difference in hospitalisation cost 6 times higher after adjustment for confounding factors (S$263±325 vs. S$1576±585, P<0.001) 2) Shorter time to see a 1-point change using the 7-point SGA vs. 3-point SGA (median 1 month vs. 3 months, P=0.002) 3) Likelihood of a 1-point change is 6.7 times greater in the 7-point SGA vs. 3-point SGA (OR 6.74, 95% CI 2.88–15.80, P<0.001) |
| Lim et al. 2016 | Prospective cohort | Inpatient malnourished adults ≥18 years N=67 | Patients assessed using the 7-point SGA and conventional SGA, received nutritional intervention and followed up after discharge. Patients were reassessed at 1, 3 and 5 months. The 7-point SGA was tested for validity against the BMI, MAC, hand grip measurements, QOL determined using EQ-VAS. SGA was compared with 7-point SGA for validity, interrater agreement, likelihood of detecting a change | A: SGA 7-point | P: 93% (moderate) 7% (severe) | 1) 7-point SGA positively correlated with: a) BMI (r=0.77, P<0.001) b) MAC (r=0.84, P<0.001) Level of agreement between the 7-point SGA and 3-point SGA, 100% (κ=1, P<0.001) 2) Shorter time to see a 1-point change using the 7-point SGA vs. 3-point SGA (median 1 month vs. 3 months, P=0.002) 3) Likelihood of a 1-point change is 6.7 times greater in the 7-point SGA vs. 3-point SGA (OR 6.74, 95% CI 2.88–15.80, P<0.001) |
| Paton et al. 2004 | RCT | Inpatient adults with TB aged 18–69 years N=56 | Patients on antituberculous therapy were randomly assigned to receive standard nutritional counseling or nutritional counseling to increase their intake (55 kcal/kg) via diet and supplements (+600 to 900 kcal/25 to 37.5 g protein daily) for 6 weeks. Body composition was measured by dual-energy X-ray absorptiometry and physical function by maximum grip strength. All patients admitted within one month. Nutrition screening was performed within 72 hours. Those at risk of malnutrition were then assessed with SGA. Logistic regression used to determine the impact of factors on malnutrition. Financial impact analysis of coding of malnutrition as a comorbidity was also performed | S: BMI <20 kg/m² | All recruited patients reported to have muscle wasting | 1) Nutritional supplement vs. control group at week 6: a) Increase in body weight (2.57 ± 1.78 vs. 0.84 ± 0.89 kg, P=0.001) b) Total lean mass (1.17 ± 0.93 vs. 0.04 ± 1.26 kg, P=0.006) c) Higher grip strength (2.97 ± 3.11 vs. 0.65 ± 4.48 kg, P=0.016) d) Higher caloric intake (2562 ± 460 kcal/day vs. 1940 ± 440 kcal/day, P=0.001) and remained higher at week 12 (P=0.001) |
| Raja et al. 2004 | Prospective cohort | Inpatient admitted to two general medical and two surgical wards aged 14–97 years N=658 | Patients were screened within 24 hours of admission. The sensitivity, specificity, best cut-off score, and interrater reliability for 3-MinNS were determined | A: SGA S: MST | P: SGA 14.7% R: MST 22.3% | 1) Malnutrition coding a) Leads to DRG change in 24 of 105 malnutrition episodes b) Increases the complexity (22.9%) of patient care as determined by expected cost weights (P<0.001) and expected hospital LOS (P<0.001) 2) Malnourished vs. normal nutrition patients: Higher percentages for readmission (7.6% vs. 2.6%) a) Higher LOS (7.9 days vs. 3.8 days) b) Higher mortality (15.3% vs. 12.5%) c) Increased financing by 59.7% 3) Lost hospital income of $S23,365 ($US12,710) in additional revenue for the 24 patients with DRG change 4) If none of the 105 malnutrition episodes had malnutrition coding, it would have led to losses of $S30,527 ($US16,617) in hospital revenue |

(Continued)
Table 2. (Continued)

| Author, year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|-------------|------------|-------------------|--------------|----------------------------------------|----------------------------------------|---------------|
| Salazar et al.28 | Retrospective cohort | Non-critically ill adults inpatients in general or high dependency wards on PN | Patients identified from a database, on PN for >5 days stratified into 1) conventional IVLE (sahih ole 0.2), 2) alternative IVLE (olive, MCT, and fish oil). Clinical outcomes analysed between conventional IVLE and alternative IVLE. Regressions were conducted to determine the relationship outcome variables with types of IVLE. | N/A | N/A | 1) No differences in mortality, readmission, LOS and infection between conventional and alternative IVLEs group. 2) Change in day 5 CRP between conventional and alternative IVLEs (8.43 ± 112.2 g/L vs. –41.2 ± 106.4, adjusted P=0.01) |
| Tan et al.29 | Prospective cohort | Inpatient adults on HD aged 21–75 years | Patient nutritional status assessed and anthropometry (dry weight, height and BMI) were collected. Dietary intake was assessed with a 3-day diet recall, and the daily energy and protein intake calculated. Daily energy and protein requirements were estimated using predictive equations. Additional information was obtained from the patient records. | A: SGA P: 46% (moderate) 6% (severe) | | 1) Malnourished patients had longer hospital LOS (SGA-A 11.0 ± 10.1 vs. SGA-B 27.3 ± 46.5 vs. SGA-C 21.0± 23.8, P=0.03) 2) 18% unable to meet at least 70% of daily energy 3) 24% unable to meet at least 70% of protein needs 4) Only 57% of the patients were referred to dietitian |
| Wong et al.29 | RCT | Inpatient adults aged ≥21 years | Patients with stage II–IV pressure ulcers were randomly assigned to receive a HMB/arginine/glutamine mixture twice daily alongside oral nutritional supplement (n=12) or standard care with oral nutritional supplements (n=12) for 2 weeks. Biochemistry, pressure ulcer area, depth, proportion of viable tissue and pressure ulcer scale for healing (PUSH) scores were measured weekly. | A: SGA P: 65% (all) 6% (intervention) 67% (placebo) | | 1) Wound area did not decrease significantly for both groups 2) The proportion of viable tissues increased within 2 weeks on HMB/arginine/glutamine supplementation (P=0.02) 3) PUSH scores improved within 1 week of supplementation (P=0.0013) |
| Wong et al.30 | Retrospective observational | Inpatient adults on PN N=192 | Demographics, diagnoses, ICU admissions, hospital LOS, indication and duration of PN, reasons for stopping PN, central line insertions, types of central lines and number of line changes were recorded. Short-term avoidable PN group = started on PN and terminated within 5 days. Unavoidable PN group = PN days >5 days. Manpower hours and costs, PN costs were also calculated | N/A | N/A | 1) Median TPN administration 9 days. Majority were surgical patients (90.1%) and 30-day mortality 21.4% 2) Costs for PN and manpower ~$1.2 million for 2791 PN days 3) 88.8% were short-term TPN and avoidable when patients progressed to oral/enteral diet within 5 days, equivalent to $59,154.42 ($42,183.15 was payable by the patients) 4) Daily costs for TPN is higher for patients on short-term PN (P<0.001) |
| Wong et al.31 | Retrospective observational | Inpatient and outpatient adults with gastrointestinal lymphomas aged ≥18 years N=158 | Chemotherapy patients were stratified into 1) receiving TPN and bowel rest and 2) not receiving TPN and bowel rest. Clinical outcomes of perforation, infection and survival compared between the two groups. | N/A | N/A | 1) With vs. without TPN and bowel rest a) The perforation rate similar (8.5% vs. 2.7%, P=0.197, OR 0.87, 95% CI 0.1–5.9) b) Overall survival was similar (OR 1.23, 95% CI 0.50–3.03) c) The TPN group had a higher risk of infection (HR 3.8, 95% CI 1.58–9.22) 2) TPN and bowel rest did not reduce the risk for perforation for patients: a) With aggressive lymphoma (TPN vs. no TPN: 6.7% vs. 5.4%, P=0.45) b) With small bowel involvement (TPN vs. no TPN: 12.5% vs. 18.5%, P=0.56) c) Treated as inpatient (TPN vs. no TPN: 8.5% vs. 8.3%, P=0.98) 3) Subgroup of patients treated on an inpatient basis, the TPN group demonstrated a) Near fourfold higher risk for infection (HR 3.8, 95% CI 1.04–13.70) b) 80% longer hospital LOS (mean LOS ratio 1.8, 95% CI 1.04–3.03) |

BMI: body mass index; CAMA: corrected arm muscle area; CI: confidence interval; CRP: C-reactive protein; DRG: diagnosis-related group; EQ-5D VAS: EQ-5D visual analogue scale; HR: hazard ratio; IVLE: intravenous lipid emulsion; LOS: length of stay; MAC: mid-arm circumference; MCT: medium chain triglyceride; MNA: mini nutritional assessment; MST: malnutrition screening tool; NIRS 2002: nutritional risk screening 2002; OR: odds ratio; PEG: percutaneous endoscopic gastrostomy; PN: parenteral nutrition; QOL: quality of life; RCT: randomised controlled trial; SGA: subjective global assessment; SNAQ: short nutritional assessment questionnaire; TPN: total parenteral nutrition; TTSH NST: Tan Tock Seng Hospital nutrition screening tool; 3min-NS: 3 minute nutrition screening tool.
### Table 3. Nutritional studies on patients in critical care settings.

| Author | Year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|--------|------|------------|-------------------|--------------|------------------------------------------|----------------------------------------|---------------|
| Lew et al. | 2017 | Prospective observational cohort | ICU adult patients aged ≥18 years with 24 hours stay N=439 | Demographics, nutrition status, 28-day mortality, ICU-LOS and parameters known to be covariates for mortality and ICU LOS were collected. Multivariable regressions performed for: 1) presence vs. absence of malnutrition 2) dose-dependent association for each one point decrease in the 7-point SGA | A: mNUTRIC, SGA,7-point | P: SGA 7-point 28% (all) 22% (survivor) 42% (non-survivor) | 1) Malnutrition was associated with an increased risk of 28-day mortality (adj RR 1.33, 95% CI 1.05–1.69) 2) Each 1-point decrease in 7-point SGA was associated with 8% increase in the risk of 28-day mortality (adj RR 1.08, 95% CI 1.00–1.16) 3) No significant association between malnutrition and ICU-LOS 4) Malnourished patients were older (P=0.001), had lower BMI (<0.001) and higher disease severity vs. well nourished |
| Lew et al. (a) | 2017 | Prospective observational cohort | ICU adult patients aged ≥18 years with 24 hours stay Same population as Lew et al. 2017 N=439 | Nutritional assessment by a dietitian within 48 hours of admission. mNUTRIC was retrospectively calculated at the end of the study. Patients were followed until discharge/death for up to one year. *κ*-statistics and C-statistics performed for agreement. Multivariate logistic regression was used to quantify the association between high mNUTRIC, malnutrition and their combination with hospital mortality | A: mNUTRIC, SGA,7-point | P: SGA 7-point 28% (all) 22% (survivor) 42% (non-survivor) | 1) 67.9% had high mNUTRIC but only 28% were malnourished 2) Poor concordance between the mNUTRIC and SGA 3) Combination of mNUTRIC and SGA had better discriminative ability (0.70, 95% CI 0.66–0.75) than either of these tools alone (mNUTRIC: P=0.002 and SGA: P<0.001) 4) High mNUTRIC associated with higher adjusted odds for hospital mortality vs. malnutrition (adj OR 5.32, 95% CI 2.15–13.17, P<0.001 and 4.27, 95% CI 1.03–17.71, P=0.046, respectively) |
| Lew et al. (b) | 2018 | Prospective observational cohort | ICU adult patients aged ≥18 years with >48 hours of mechanical ventilation Subgroup of Lew et al. 2017 N=252 | Nutritional assessment was performed and patients were prescribed an appropriate enteral or parenteral feeding regime. Nutrition support provided was calculated 14 days (maximum). Associations between the dose of energy and protein intake and 28-day mortality in high-risk patients (EN ≤6 days vs. ≥7 days) were evaluated with multivariable Cox regressions | A: mNUTRIC, SGA,7-point | P: SGA 7-point 26% (all) 22% (survivor) 33% (non-survivor) 29% (short-term EN) 24% (long-term EN) | 1) Non-surviving patients had a higher mNUTRIC score and were more likely to be malnourished (33.3% vs. 22.6%, P=0.048) 2) For high-risk patients with short-term EN, every 10% increase in goal caloric intake was related to an increased hazard of 28-day mortality (adj HR 1.37, 95% CI 1.17, 1.61) 3) For high-risk patients with short-term EN, every 10% increase in goal protein intake was associated with a lower hazard of 28-day mortality (adj HR 0.78, 95% CI 0.66, 0.93) 4) For high-risk patients with longer-term EN, each 10% increase in goal protein intake was associated with a lower hazard of 28-day mortality (adj HR 0.87, 95% CI 0.75, 1.01) |
| Lew et al. | 2019 | Prospective observational cohort | ICU adult patients aged ≥18 years with 24 hours stay Same population as Lew et al. 2017 N=440 | A prognostic model (GLIMPSE) to predict 28-day mortality built from ICU patient data, consisting of: 1) disease severity measured by the mNUTRIC score 2) nutritional status by 7-point SGA 3) cardiopulmonary resuscitation before ICU admission. Association between dose of nutrition support and mortality risk was evaluated using logistic regressions, with stratification of low and high-risk groups and days of EN (≤6 days vs. ≥7 days) | A: mNUTRIC, SGA,7-point | P: SGA 7-point 28% (all) 22% (survivor) 42% (non-survivor) | 1) Survivors were more likely to be well-nourished vs. non-survivors (22.7% vs. 41.5%, P<0.001) 2) Similar prevalence of malnutrition between short and longer-term EN patients (29.2% vs. 24%, P=0.347) 3) Associations between caloric and protein intakes and 28-day mortality were independent of baseline nutritional status, after further stratification of nutritional status in both low and high GLIMPSE groups 4) For high-risk patients with short-term EN, each 10% increase in: a) Goal energy was associated with increased odds of 28-day mortality (adj OR 1.60, 95% CI 1.19–2.15) b) Goal protein was associated with increased odds of 28-day mortality (adj OR 1.47, 95% CI 1.12–1.86) | (Continued) |
| Author, year | Study type | Population & size | Intervention | Screening (S) & assessment tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|-------------|------------|-------------------|--------------|--------------------------------------|---------------------------------------|--------------|
| Mukhopadhyay et al. **2017** | Prospective observational cohort | Medical ICU adult patients aged ≥ 18 years with 24 hours stay N = 401 | Data collected include mNUTRIC score, demographics, BMI, use of mechanical ventilation (MV), vasopressor drugs, and renal replacement therapy. Subgroup analysis of patients who received mechanical ventilation ≥ 48 hours and nasogastric tube feeding or TPN. Multivariate logistic regression model was performed where outcome of interest is 28-day mortality | A: mNUTRIC Nil | 1) 12% of low mNUTRIC score group died vs. 34% of high mNUTRIC score group 2) In patients who received MV, differences were noted between high (147, 53.8%) and low (126, 46.2%) mNUTRIC groups in terms of: a) mortality (53.36% vs. 16, 12.7% P < 0.001) b) ICU LOS (median (IQR) 5.3 (3–9) vs. 3.5 (2–7) days, P < 0.014) c) duration of MV (median (IQR) 3.3 (1.5–5.7) vs. 2.1 (1.25–3.75) days, P < 0.001) 3) For subgroup analysis, inverse correlation was observed between energy intake during MV and LOS in the hospital (P < 0.001) a) Every 1000 Kcal/day higher energy intake was associated with a shorter 2.2 days of LOS b) Every extra 1000 Kcal/day was associated with a shorter 1.1 days of LOS in the low mNUTRIC group vs. 2.9 days in the high mNUTRIC group 4) Factors associated with 28-day mortality: a) mNUTRIC score (OR 1.48, 95% CI 1.25–1.74, P < 0.001) b) use of vasopressor drug (OR 2.31, CI 1.28–4.15, P = 0.005) c) BMI (OR 0.92, CI 0.87–0.97, P = 0.002) | |
| Mukhopadhyay et al. **2018** | Prospective observational cohort | Medical ICU adult patients aged ≥ 21 years N = 48 | Measurement of rectus femoris cross-sectional area by ultrasound on ICU days 1, 3, 7, and 10. Clinical data (clinical outcomes, APACHE II score, mNUTRIC score, SOFA score, and biochemistry) collected. Linear mixed effects model was used to identify the individual component of mNUTRIC to predict muscle loss | A: mNUTRIC Nil | 1) High mNUTRIC score (> 5) group lost more muscle vs. low (≤ 5) group (P < 0.001) 2) High vs. low mNUTRIC scores a) lower BMI (22.3, 95% CI 20.9–26.4 vs. 28.2, 95% CI 25.2–31, P < 0.001) b) higher Charlson comorbidity index (5, 95% CI 2–7 vs. 1 (95% CI 0–3, P = 0.007) c) stayed longer in the ICU (7, 95% CI 3–11 vs. 4, 95% CI 3–5, P = 0.003) d) stayed longer in hospital (19, 95% CI 11–44 vs. 8.5, 95% CI 8–10, P < 0.001) e) No difference in mortality | |

Adj: adjusted; BMI: body mass index; EN: enteral nutrition; HR: hazard ratio; ICU: intensive care unit; IQR: interquartile range; LOS: length of stay; mNUTRIC: modified nutrition risk in ICU; MV: mechanical ventilation; OR: odds ratio; RR: relative risk; SGA: subjective global assessment; TPN: total parenteral nutrition.
Table 4. Nutritional studies on patients in long-term care settings.

| Author, year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|--------------|------------|--------------------|--------------|------------------------------------------|----------------------------------------|---------------|
| **Chan et al.**<sup>39</sup> 2010 | Cross-sectional study with prospective collection of mortality data | Nursing home residents <i>N</i>=154 | Demographic details, nutritional assessment, functional status and comorbidities were evaluated. Log-rank tests performed to compare survival times for subjects with differential BMI (≥ or <18.5 kg/m<sup>2</sup>) and MNA (≥ or <17) values at baseline | A: MNA S: MNA SF | P: MNA 39% R: MNA-SF 97% | 1) Independent factors associated with mortality a) Increased age (OR 1.05, 95% CI 1.01–1.09) b) Lower Barthel score (OR 1.01, 95% CI 1.01–1.02) c) Low BMI (OR 3.08, 95% CI 1.40–6.78) d) Low MNA (OR 3.03, 95% CI 1.43–6.41) (all <0.05) 2) Association between low BMI and mortality remained significant (<0.027) after adjustment for patient’s age, gender, Barthel’s and Charlson’s scores and presence of prior nutritional intervention 3) Log-rank test indicated clear reduction in survival times with lower BMI (P=0.027) and MNA (P=0.003) 4) Mortality rate 25.3% |
| **Wong et al.**<sup>40</sup> 2019 | Cross-sectional study | Nursing home residents on tube feeding <i>N</i>=240 | A cross-sectional survey to determine the prevalence and incidence of HEN and swallowing impairment, the demographic details of nursing home residents, the type of HEN delivery and feeds used in the nursing home, the nursing manpower for HEN administration | Nil | Nil | 1) The mean length of time residing in the nursing home ~46 months, with a maximum of 228 months 2) >50% of residents on HEN received nasogastric tube feeding for more than 36 months 3) An incidence rate of 15.7 per 1000 people-years and a point prevalence of 136.6 per 1000 residents for HEN 4) An incidence rate of 433.0 per 1000 people-years, with point prevalence of 385.6 per 1000 residents for chewing/swallowing impairment 5) Median monthly HEN cost S$799.47 per resident (IQR 692.11, 940.30) 6) Nursing costs for feeding contributed to 63% of total HEN costs |
| **Yap et al.**<sup>41</sup> 2003 | Retrospective observational study | Nursing home residents <i>N</i>=106 | Resident’s biochemical, demographic, medical diagnoses and functional status at admission were recorded. Nutritional assessment was performed using clinical impression | Clinical impression R: 22% | 1) 22% of residents appeared undernourished 2) 21% dependent on feeding assistance 3) 48% had probable cognitive impairment 4) 41% were severely disabled |

BMI: body mass index; CI: confidence interval; HEN: home enteral nutrition; IQR: interquartile range; MNA: mini nutritional assessment; MNA-SF: mini nutritional assessment – short form; OR: odds ratio.
| Author, year | Study type | Population & size | Intervention | Screening (S) & assessment (A) tools used | Malnutrition prevalence (P) & risk (R) | Main findings |
|-------------|------------|-------------------|--------------|------------------------------------------|---------------------------------------|--------------|
| Kanesvaran et al.42 2011 | Cross-sectional | Cancer patients aged >70 years attending outpatient geriatric oncology clinic N=249 | CGA data were collected from patients (including functional status, ADLs, iADLs, hand grip strength, comorbidity, cognitive status, patient’s affect, polypharmacy, and nutritional status). Univariate and multivariate analyses were performed to identify significant prognostic factors within the CGA. Concordance between predicted and observed response of the score was evaluated. Clinical and nutritional data from the Singapore HIV Observational Cohort Study was used. Intention-to-treat Cox models were used to determine the predictors of survival. | S: NSI | R: 44.2% (moderate) 28.9% (high) | 1) Risk of dying increased with poor NSI score (moderate vs. good: HR 1.61, 95% CI 1.08–2.41; high vs. good: HR 2.95, 95% CI 1.95–4.47) 2) Patients with high malnutrition risk (high vs. low: HR 2.69, 95% CI 1.64–4.10) have shorter survival and were independent predictors of survival |
| Paton et al.43 2011 | Retrospective cohort | Outpatient adults with HIV started combination ART N=479 | CGA data were collected from patients (including functional status, ADLs, iADLs, hand grip strength, comorbidity, cognitive status, patient’s affect, polypharmacy, and nutritional status). Univariate and multivariate analyses were performed to identify significant prognostic factors within the CGA. Concordance between predicted and observed response of the score was evaluated. Clinical and nutritional data from the Singapore HIV Observational Cohort Study was used. Intention-to-treat Cox models were used to determine the predictors of survival. | BM1 (17.0–18.4 = mild malnutrition and <17.0 = moderate to severe malnutrition) | R: 1.45% mild 16% moderate to severe | 1) Median duration of follow-up 2.4 years 2) Median survival 5.2 years from the start of ART 3) Moderate to severe malnutrition significant independent predictor of death (HR 2.19, 95% CI 1.29–3.73, P=0.004 for BMI <17 vs. BMI >18.5) 4) Malnutrition did not affect the magnitude of the increase in CD4 cell count at 6 or 12 months |
| Rajasekaran et al.44 2016 | Prospective cohort | Newly diagnosed cancer patients aged >70 years attending geriatric oncology clinic N=244 | CGA data were collected from patients. Logistic regression models were fitted to assess the association of various variables with mild to severe caregiver burden. | S: NSI | R: 43.9% (moderate) 29.9% (high) | 1) Higher OR for caregiver burden in a) Moderate risk vs. good nutrition (OR 2.48, 95% CI 1.01–6.13, P=0.013) b) High risk vs. good nutrition (OR 3.99, 95% CI 1.58–10.05, P=0.013) |
| Tan et al.45 2016 | Retrospective observational cohort | Cancer patients aged >70 years attending outpatient geriatric oncology clinic N=249 | CGA data were collected from patients. Logistic regression models were fitted to assess the association of various variables with high nutritional risk. | S: NSI | R: 73.9% (moderate–high, no distinction between groups) | 1) Moderate to high vs. low nutritional risk: a) Primary tumour in the GI tract (73% vs. 51%, P=0.02) b) ECOG performance status 2–4 (76% vs. 42%, P<0.001) c) Advanced stage of disease at diagnosis (90% vs. 71%, P=0.02) d) Depression (36% vs. 6%, P=0.02) e) Low MMSE scores (<24 points) (38% vs. 17%, P=0.02) f) Imposed mild to severe burden to their caregivers (27% vs. 11%, P<0.02) g) More than 4 prescribed drugs (66% vs. 44%, P=0.02) h) Presence of geriatric syndromes (69% vs. 37%, P=0.02) i) Lower median BMI values (20.9 vs. 23.7, P<0.001) j) Lower haemoglobin levels (<12 g/dL) (<33 vs. 12 g/dL, P=0.0011) k) Lower albumin levels (25.0 vs. 34.0 g/dL, P<0.001) 2) Independent factors associated with moderate to high nutritional risk: a) Stage 3–4 at diagnosis (OR 2.54, 95% CI 1.14–5.69, P=0.023) b) ECOG performance status 2–4 (OR 3.04, 95% CI 1.57–5.88, P=0.001) c) Depression (OR 5.99, 95% CI 1.99–18.02, P=0.001) d) Haemoglobin levels <12 g/dL (OR 3.03, 95% CI 1.54–5.94, P=0.001) |
| Tan et al.46 2000 | Prospective cohort | Outpatient adults on chronic peritoneal dialysis programme N=37 | CGA data were collected from patients. Logistic regression models were fitted to assess the association of various variables with moderate to high nutritional risk. | S: NSI | R: Serum albumin of <33 g/L or a BMI of <19, or a DPI of <0.8 g per kilogram of body weight taken as indicators | 1) When serum albumin of <33 g/L, or BMI of <19 or daily DPI <0.8 g/kg body weight were taken as indicators of malnutrition, 51% 14% and 39% of dialysis patients were malnourished 2) 76% of patients were deemed to be malnourished if any one of the indicators was present. |

ART: antiretroviral therapy; BMI: body mass index; CGA: comprehensive geriatric assessment; CI: confidence interval; DPI: daily protein intake; ECOG: Eastern Cooperative Oncology Group; GI: gastrointestinal; HIV: human immunodeficiency virus; HR: hazard ratio; MMSE: mini-mental state examination; NSI: nutrition screening initiative DETERMINE checklist; OR: odds ratio.
A higher malnutrition prevalence of 3.9% has been found in specific frailty subgroups of the SLAS study populations.\textsuperscript{14} Another cross-sectional study of SLAS-1 and SLAS-2 showed that 14% of independent elderly with sarcopenia were at risk of malnutrition, compared to 4.7% of non-sarcopenic individuals.\textsuperscript{10} The same authors also looked at those elderly adults with mild cognitive impairment and reported a 31.5% malnutrition prevalence rate.\textsuperscript{11}

In a study of socioeconomically disadvantaged Singaporeans who received public assistance, a malnutrition prevalence of 2.8% was reported using the MNA.\textsuperscript{7} The study found recipients residing in nursing homes have a higher risk of malnutrition compared to community-dwelling adults (68.2% vs. 50.4%, P=0.007), but this was not replicated when the NSI was used.\textsuperscript{7}

In the outpatient setting, none of the studies presented malnutrition prevalence data. Three studies performed nutritional screening using the NSI on a group of geriatric cancer patients attending an outpatient clinic and reported that 43.9% were at moderate risk and 29.9% at high risk of malnutrition.\textsuperscript{12, 44, 46} An older study reported that 30.5% of HIV outpatients have malnutrition\textsuperscript{43} using a BMI of less than 17, which is not an appropriate indicator of nutritional status.\textsuperscript{44}

### Clinical outcomes of malnutrition

Lim et al.\textsuperscript{20} found malnutrition to be a significant predictor of overall mortality (adjusted hazard ratio 4.4, 95% confidence interval (CI) 3.3–6.0, P<0.001), resulted in longer hospital stays (6.9 ± 7.3 days vs. 4.6 ± 5.6 days, P<0.001) and a higher risk of 15-day readmission (adjusted relative risk (RR) 1.9, 95% CI 1.1–3.2, P=0.025). The mortality rate was also significantly higher (P<0.001) in the malnourished group at one year.\textsuperscript{20}

Patients with reduced nutritional status were also more likely to be discharged with higher-level care (adjusted odds ratio (OR) 2.46, 95% CI 1.27–4.70).\textsuperscript{25} Malnourished patients were found to have poorer clinical outcomes compared to well-nourished patients in terms of a higher prevalence of hospital length of stay (LOS), 3-month readmission rates, 6-month mortality rate and lower modified Barthel index score.\textsuperscript{25}

In a specific dialysis patient population, Tan et al.\textsuperscript{29} found that haemodialysis patients who were malnourished were more likely to have longer LOS (SGA-A 11.0 ± 10.1 vs. SGA-B 27.5 ± 46.5 vs. SGA-C 21.0 ± 23.8, P=0.03) and only 57% of malnourished patients were seen by dietitians.

### Frailty and sarcopenia in the elderly population

A considerable amount of research investigated frailty and sarcopenia in the elderly population. The SLAS-1 found that elderly at risk of malnutrition were more likely to have three or more comorbid medical conditions (OR 3.14, 95% CI 2.11–4.69), were hospitalised (OR 2.24, 95% CI 1.49–3.36), functionally dependent for activities of daily living (ADL) (OR 1.72, 95% CI 1.41–2.11) and to self-report poor or fair health (OR 2.29, 95% CI 1.91–2.74).\textsuperscript{14}

Elderly individuals at risk of malnutrition or malnourished were more than twice as likely to be pre-frail and more than four times likely to be frail.\textsuperscript{15} The presence of cognitive impairment was also associated with increased odds (OR 4.19, 95% CI 2.83–6.20, P<0.001) of the risk of malnutrition. The odds increase to 7.27 (95% CI 5.30–9.99) for the pre-frail/frailty population with cognitive impairment.\textsuperscript{6}

Malnutrition conferred significantly higher odds of sarcopenia in women (OR 5.71, 95% CI 1.13–28.84, P=0.035),\textsuperscript{10} and is an independent risk factor for pre-sarcopenia (RR 7.53, 95% CI 1.20–47.51, P=0.032) and sarcopenia (RR 11.91, 95% CI 2.85–49.77, P=0.001).\textsuperscript{11} Wei et al.\textsuperscript{14} found the prevalence of disability in ADL increased among elderly who were at risk of frailty or were pre-frail (40.2% vs. 16.9%; OR 1.88, 95% CI 1.40–2.53) when compared with well-nourished elderly.

Older adults who were at risk of malnutrition or malnourished were also associated with increased odds of pre-frailty (OR 2.76, 95% CI 1.86–4.10) and frailty (OR 4.10, 95% CI 1.41–11.19).\textsuperscript{15} Individuals who were pre-frail/frail were less likely to revert to a robust, healthy state when they were malnourished or at risk of malnutrition (OR 0.26, 95% CI 0.10–0.67).\textsuperscript{15} At the end of the SLAS-1 and SLAS-2 studies, a nutritional improvement was associated with decreased 10-year mortality rates (hazard ratio (HR) 0.43, 95% CI 0.23–0.80).\textsuperscript{16}

### Oral, enteral and parenteral nutrition support

Limited randomised controlled trials (RCTs) on nutritional intervention were available and were mostly performed on patients with specific diseases.\textsuperscript{26, 30} Paton et al.\textsuperscript{26} assigned patients with tuberculosis to receive either standard nutritional counselling (control group) or nutritional counselling with ONSs for 6 weeks. The intervention group had a significantly greater increase in weight (2.57 ± 1.78 vs. 0.84 ± 0.89 kg, P=0.001), total lean mass (1.17 ± 0.93 vs. 0.04 ± 1.26 kg, P=0.006) and grip strength (2.79 ± 3.11 vs. –0.65 ± 4.48 kg, P=0.016).

Wong et al.\textsuperscript{30} randomly assigned patients with stages II–IV pressure injuries to receive a β-hydroxy β-methylbutyrate (HMB), arginine and glutamine mixture twice daily in addition to ONSs for 2 weeks. Pressure ulcer scale for healing (PUSH) scores showed a significant improvement within one week of supplementation for the experimental group (P=0.013), but the wound area did not improve. However, the proportion of viable tissues increased within 2 weeks on supplementation (P=0.02).

Lim et al.\textsuperscript{22} performed a pre- and post-intervention study on the effect of dietetic follow-up for malnourished patients previously admitted to hospitals. Patients who received inpatient nutritional intervention and outpatient dietetic follow-up/home visits achieved a higher quality of life (EQ5D VAS pre: 61.2 ± 19.8 vs. post: 71.6 ± 17.4, P<0.001), as well as improved weight (pre: 44.0 ± 8.5 kg vs. post: 46.3 ± 9.6 kg, P<0.001) and handgrip strength (pre: 15.1 ± 7.1 vs. 17.5 ± 8.5 kg force, P<0.001).\textsuperscript{22}
IVLEs (olive, medium chain triglyceride and fish oil). The authors found no differences in mortality, infection or readmission rates and hospital LOS between the groups.28 There was, however, a significant change in C-reactive protein at day 5 between conventional and alternative IVLEs (8.43 ± 112.2 g/L vs. -41.2 ± 106.4 g/L, adjusted P=0.01).28

Wong et al.32 investigated the effects of total parenteral nutrition (TPN) on perforation risk for gastrointestinal lymphoma. The authors compared patients on chemotherapy receiving TPN and bowel rest with those not receiving TPN and bowel rest. Perfusion rates in both groups were similar (8.5% vs. 2.7%, P=0.197; OR 0.87, 95% CI 0.1–5.9) and the TPN group had a higher risk of infection (HR 6.02, 95% CI 1.58–22.92).

There were only two studies related to EN. Chong and Vu18 followed outpatients for a change of percutaneous endoscopic gastrostomy (PEG) at 6-monthly intervals and found that abnormal nutritional status (OR 0.074, 95% CI 0.016–0.348, P=0.0001) was predictive of mortality risks. However, nutritional status was quantified using BMI of less than 20 kg/m² instead of using validated nutritional assessment tools. Wong et al.40 recently surveyed residents on EN in nursing homes, and reported an incidence rate of 15.7 per 1000 people-years and a point prevalence of 136.6 per 1000 residents on EN.

Critical care nutrition

Mukhopadhyay et al.33 explored the association of the mNUTRIC score with outcomes in medical ICU patients. Significant differences in mortality (36% vs. 12.7%, P<0.001), ICU LOS (5 vs. 3.5, P<0.014) and mechanical ventilation duration (3.3 vs. 2.1, P<0.0012) between high and low mNUTRIC groups were reported.33 Via a univariate linear regression, a higher mNUTRIC was associated with higher risk of 28-day mortality (adjusted RR 1.33, 95% CI 1.05–1.61).35 These findings concluded the mNUTRIC to be an unsuitable nutritional assessment tool in the ICU.37

In a retrospective analysis of inpatients receiving PN, Wong et al.31 reported that the related costs for PN were approximately $1.2 million for 2791 PN days. Thirty-six cases (18.8%) with a cost of $59,154.42 were considered to be unnecessary. A recent research survey performed in local nursing homes reported a median monthly EN cost per resident of $799.47 (IQR 692.11, 940.30).40 Nursing costs involved in enteral feeding were found to be the main contributor to overall costs (63%).40

Discussion

This paper is the first scoping review targeted at local studies on nutrition-related research in inpatient, outpatient and community settings. The majority of the research included nutritional screening and assessment, and the tools used have progressed over the years. One of the reasons why nutrition screening/assessment is more widely researched could be due to the lack of funding for nutritional intervention studies in Singapore.

From this review, the prevalence of malnutrition in Singapore ranges from 14.7% to 65.0% in acute care,19 20 25 27, 29 30 28% in the ICU,35 36 39% in long-term care32 and 2.8–31.5% in community (elderly population) settings.6 11 14 15

The local figures appear similar to other developed countries.2 Other figures worth noting are the incidence rate of 15.7 per 1000 people-years and a point prevalence of 136.6 per 1000 residents on EN,40 which provides us with a baseline number for comparison in future studies.

One of our concerns was the impact of food insecurity on malnutrition. A recent survey by the Lien Foundation showed that 19% of 236 participants reported severe food insecurity.66 In this review, we found that malnutrition prevalence was higher in Singaporeans of lower socioeconomic status7 than the general populations in the SLAS-1 and SLAS-2 studies. This finding indicates that food insecurity could be a significant contributor to malnutrition.6 13 Future studies will need to assess the degree of malnutrition in individuals with food insecurity and ways to mitigate the issue.
More research is also required in the area of nutrition support. Only three observational studies on PN were identified within the past 20 years,38, 31, 32 and more interventional and economic evaluation studies are necessary to determine the clinical and cost-effectiveness of using PN in a local context. There was also a limited number of EN studies, particularly in acute care settings. While more studies were done on critical care nutrition,23, 38 these studies were based on the same cohort. One of the observations made is the lack of cross-institution research. As Singapore is a small nation, pooling of data between institutions may be a viable option to achieve appropriate sample sizes for analysis.

There is a lack of direct nutritional support and cost-effectiveness studies. Only one study showed that hospital costs in malnourished patients were three times higher than in well-nourished patients of the same diagnosis-related group.20 The benefits of the provision of nutritional support have been well documented in patients who are malnourished or at risk of malnutrition.67 Similarly, in community and nursing homes, ONSs reduced hospitalisation and led to cost savings when used consistently for 3 months.58 Only one study in this review reported the cost of EN in nursing homes.95

Further local studies are necessary to determine the cost-effectiveness of EN in this population and to ascertain if current medical nutrition reimbursement in Singapore is adequate, as a recent systematic review reported a trend for cost savings and improvement in outcomes of patients on home EN.59

Limitations
We did not perform risk of bias of the evidence as a scoping review does not aim to appraise the literature critically. However, we have incorporated the use of the PRISMA-ScR checklist to ensure that the data extracted are presented in a structured method. Multiple reviewers were also included to reduce the error and increase the reliability of this review.

As this is a scoping review, the papers identified are wide-ranging and may not be sufficiently focused. However, we have classified extensive literature within a few subtopics to provide a better understanding of the available nutritional research in Singapore. We have also included some studies that only used the controversial mNUTRIC scoring tool, which does not contain any components of nutritional assessment.23, 34 However, these studies were included as the mNUTRIC was initially designed with an intention of determining nutrition risk in the ICU population.

We were also only able to provide a range of figures for the prevalence of malnutrition, instead of a more accurate point prevalence due to the study designs and heterogeneity of the studies available. Despite the limitations, we are confident that this is the best representation of the malnutrition figures to date among the various populations in Singapore.

Conclusions
Nutritional research is gaining traction in Singapore, but the majority of the studies focus on nutritional screening and assessment, rather than on intervention. Malnutrition rates in Singapore appear to be similar to other developed countries, and more needs to be done to address the issue, considering malnutrition’s implications for health outcomes and the use of other resources. We suggest future studies to focus on nutritional intervention, cost-effectiveness/benefits analyses and specific populations such as the underprivileged, chronically ill and those dependent on nutritional support.

Authors’ contributions
A Wong and Y Huang contributed to the conception and design of the research; PM Sowa, MD Banks and JD Bauer contributed to the design of the research; A Wong and Y Huang contributed to the acquisition and analysis of the data; all authors contributed to the interpretation of the data; A Wong and Y Huang drafted the manuscript. All authors critically revised the manuscript and agree to be fully accountable for ensuring the integrity and accuracy of the work and read and approved the final manuscript.

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