

Review of dietary assessment studies conducted among Khmer populations living in Cambodia

Janelle L. Windus  | Kerith Duncanson  | Tracy L. Burrows  | Clare E. Collins  | Megan E. Rollo 

School of Health Sciences, Faculty of Health and Medicine, University of Newcastle, Newcastle, NSW, Australia

Correspondence

Janelle L. Windus, School of Health Sciences, Faculty of Health and Medicine, University of Newcastle, University Drive, Callaghan, NSW 2308, Australia.
Email: janelle.windus@uon.edu.au

Abstract

Background: Despite economic growth, Cambodia continues to have high rates of malnutrition, anaemia and nutrition-related deficiencies. Government policies promote nutrition strategies, although dietary intake data is limited. A detailed synthesis of existing intake data is needed to inform nutrition policy and practice change. This review aims to characterise and assess quality of dietary assessment methods and outcomes from individual-level ‘whole diet’ studies of Khmer people living in Cambodia.

Methods: Searches were conducted using PRISMA-ScR guidelines. Included papers reported dietary intake at an individual level for ‘whole diet’. Studies using secondary data or lacking dietary assessment details were excluded. Extracted data included dietary assessment features, nutrient/food group intakes and database.

Results: Nineteen publications (15 studies) were included, with nine carried out among children under 5 years and six among women. Eleven studies reported intake by food groups and four by nutrients, prominently energy, protein, vitamin A, iron, calcium and zinc. Inconsistent intakes, food groupings and reporting of study characteristics limited data synthesis. All but one study used 24-h recalls. Trained local fieldworkers used traditional interview-administered data collection and varied portion estimation tools. Food composition databases for analysis were not tailored to the Cambodian diet. Overall quality was rated as ‘good’.

Conclusions: We recommend the development of a best-practice protocol for conducting dietary assessment, a Cambodia-specific food composition database and a competent trained workforce of nutrition professionals, with global support of expertise and funding for future dietary assessment studies conducted in Cambodia.

KEYWORDS

Cambodia, dietary assessment, dietary intake, food composition database, review

Key points

- Fifteen studies with highly variable intake data included in the review.
- The food composition databases used were not specific to Cambodian diet.
- Minimum reporting standards and best practice protocols recommended, including in-country nutrition training.
- Lack of whole population dietary intake data indicates the need for a national survey.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2022 The Authors. *Journal of Human Nutrition and Dietetics* published by John Wiley & Sons Ltd on behalf of British Dietetic Association.

INTRODUCTION

The health of Cambodia's Khmer population continues to be adversely impacted secondary to the devastation inflicted on society during Khmer Rouge regime from 1975 to 1999.¹ Cambodia is currently classified as a low-middle income country (LMIC), with poverty manifested by high rates of poor hygiene, sanitation and nutritional status coupled with inadequate health services.^{2,3} Poor nutritional status is indicated by relatively high rates of underweight (24%), stunting (32%) and wasting (10%) among children aged under 5 years (i.e., high compared to neighbouring Thailand and Vietnam, and similar to Laos),⁴ underweight among women of reproductive age (WRA) (14%) and moderate (37%) levels of food insecurity.^{5,6} A growing proportion of malnourished women (18%) and children (2%) have overweight or obesity, amplifying the double burden of malnutrition.⁶ The prevalence of anaemia remains high for children under 5 years (56%) and women (44%),⁶ despite targeted programmes and government initiatives attempting to counter this situation. Nutritional deficiencies remain prevalent, with zinc deficiency rates of 73%–90% among children,^{7,8} 19% for folate among women, and 33% and 60% for vitamin D in children and women, respectively.⁶ Vitamin A rates (9% in 2014) in women have decreased since 2000.⁶

Dietary patterns in Cambodia reflect the communal lifestyle of the Khmer people, who share family meals that feature rice, soup, sweet stew and fish.⁹ Typical Khmer diets lack adequate meats, vegetables and fruit, reflecting widespread poverty rather than the unavailability of these food items in Cambodia.¹⁰ Energy dense snacks high in fat, sugar and salt are commonly consumed, particularly by children.¹¹ Along with condiments high in salt such as fish sauce, soy sauce and monosodium glutamate, as well as added salt, these contribute to the common unhealthy dietary patterns.

Global health agencies and non-government organisations have partnered with the Cambodian government to address key nutritional and food security issues amongst Cambodians.^{12,13} This primarily focuses on malnutrition-related strategies for mothers and children. These include the first National Nutrition Strategy 2009–2015,¹⁴ a National Nutrition Program's fast track road map for improving nutrition 2014–2020,¹⁵ the National strategy for food security and nutrition 2019–2023,² and the Cambodia Nutrition project with World Bank.¹⁶ Additionally, international researchers have conducted cross-sectional studies and interventions to inform further policy and programme development.^{12,13} Ninety percent of these studies reported being funded by external agencies, many in partnership with the Cambodian government.¹³

These strategies are consistent with the Sustainable Development Goals for ending hunger and all forms of malnutrition by 2030.¹⁷ Despite nutrition policy and

strategy prioritisation in Cambodia, there are no goals or strategies to specifically address nutritional adequacy of dietary intakes. The most specific policy reference to dietary intake is to 'increase availability of information through improved monitoring, evaluation and research' (strategy 7.5; NNS¹⁴). Currently Cambodia lacks national nutrient reference values for children aged under 5 years and adults, although, recently, the Cambodian government developed 'Cam-RDA' nutrient reference values for school-age children.¹⁸

Food consumption surveys assess the dietary intake of individuals or groups aiming to examine nutrient adequacy of population intake and also diet–disease relationships so that these can inform national nutrition and health policies.¹⁹ Individual-level dietary assessment in Khmer populations is problematic because of challenges such as estimation of individual portions eaten from shared plates.²⁰ The absence of a comprehensive Cambodian-specific food composition database (FCD) further limits any accurate evaluation of nutrient adequacy of Khmer populations and specific age groups within the population.^{21,22}

Published studies about dietary intake in LMICs often do not describe the dietary assessment methods used in a comprehensive or systematic manner.²³ Low rigour and poor study quality limit generalisability of the study findings and potentially can result in misleading recommendations or inappropriate strategy implementation.²⁴ Guidelines such as STROBE-nut²⁵ were developed to improve the global quality of nutrition intervention reporting, and the European Micronutrients Recommendations Aligned Network of Excellence (EURRECA)²⁶ tool is available for assessing the quality of dietary intake validation studies.

Our recent scoping review included 100 food and nutrition studies with Khmer living in Cambodia, of which 42 involved a nutrition intervention, 76 were dietary assessment studies and 18 involved both nutrition intervention and assessment components.¹³ Two-thirds (68%) of studies were conducted among WRA and young children, and predominantly focused on malnutrition-related issues and anaemia.¹³ Thirty-five dietary assessment studies explored a specific dietary component (vitamin A-rich foods, sugar-containing foods, snack foods) or a single food such as rice or fish, rather than having an overall or 'whole diet' focus. The review provided a comprehensive overview of nutrition research conducted in Cambodia to date, but the intentionally broad inclusion criteria, diversity of primary outcomes and variability in dietary assessment methods used limited the comparison of outcomes between the included studies. Additionally, characteristics relating to dietary assessment methods and FCDs were not the primary focus and so methodological quality was not comprehensively investigated.

To better understand the dietary intake of Khmer people living in Cambodia, in-depth analysis and

synthesis of data and the methods used in dietary assessment-specific studies were identified as an urgent need for further informing future research. In particular, there is a need for evidence relating to the relationships between nutrition and health, as well as the reporting of food and/or nutrient intakes at the individual level.²⁷

The primary aim of the current review was to characterise food and/or nutrient intake outcomes and associated dietary assessment methods in studies that evaluated ‘whole diet’ among Khmer people living in Cambodia. A secondary aim was to evaluate the quality of dietary assessment methods used in these individual-level dietary intake studies.

METHODS

The initial search was conducted in May 2020, and an updated search was performed in November 2021, following the PRISMA-ScR protocol.²⁸ The full search strategy is described in Windus et al.¹³ Briefly, five databases (Medline, CINAHL, Embase, Cochrane library and Scopus) were searched using specific keywords related to nutrition, health, diet, food and Cambodia. Grey literature searches included Google Scholar and websites for Cambodian government and several global health organisations.

After removing duplicates, each study was screened by two reviewers by title and abstract, then full-text articles were independently evaluated by two reviewers against the inclusion/exclusion criteria. Conflicts at both stages were resolved by a third reviewer. Studies were included if they were conducted among Khmer people living in Cambodia, and included dietary assessment, which could be but was not limited to observation, self-report or proxy surveys. Included papers reported dietary intake at an individual level for the ‘whole diet’. To be eligible as a ‘whole diet’, studies collected dietary intake on nutrients and/or food groups that reflected a complete dietary intake. Studies were excluded if they collected partial dietary intake such as single specified food items (e.g., rice, fish, sugar-containing snacks), one food group (e.g., meats, complementary foods, breast-milk substitutes) or foods rich in a single nutrient (e.g., vitamin A-rich foods). Qualitative studies and articles pre-dating 1993 or in languages other than English or Khmer were excluded. Studies were excluded if there was only secondary data analysis (rather than primary data), collected household-level intake, or they used indirect methods such as food balance sheets. Studies that did not report on the dietary assessment methods used or results of dietary intake were also excluded. Screening of included studies was conducted by two reviewers and 13 conflicts were resolved by discussion and consensus.

Data from included ‘whole diet’ dietary assessment studies were extracted by the lead reviewer and checked by a second reviewer. Extracted data included dietary

assessment features/tools, validation status, nutrient or food group intake measured, FCDs and nutrition adequacy standards used. Dietary assessment methods were categorised as ‘validated’ when the study indicated use of a validated tool.

The EURRECA²⁶ scoring system was selected as a quality assessment tool as a result of applicability for dietary assessment studies. Two reviewers independently scored each study based on sampling, statistics, administration, seasonality and supplements, with a score < 2.5 rated as ‘poor’, 2.5 to < 3.5 as ‘reasonable’, 3.5 to < 5.0 as ‘good’ and 5.0–7.0 as ‘very good’. Steps two and three assess correlations of validation studies and thus were not used.

RESULTS

The literature search identified 4109 titles, of which 293 full text articles were assessed for inclusion and a further 274 were excluded. Two hundred and fifty-five articles were excluded based on study type, characteristics or design, 35 were excluded because they did not report intake of the ‘whole diet’, 12 studies did not use primary data, seven studies collected household rather than individual dietary intake, and eight did not fully describe the dietary assessment methods used (Figure 1). Of the resulting 19 publications, seven reported on the same three studies, and the remaining 12 publications were individual studies. Therefore, 15 studies were included in this review, with the publications from the same study differentiated by the first author's name and year.

Eight studies reported on nutrition interventions, including three home food production interventions,^{29–33} a local food-based supplement,³⁴ iron and zinc supplements,³⁵ and a lunch provision study.³⁶ Nine were cross-sectional dietary intake assessment studies^{6,7,9,11,18,37–40} and two reported on validation of a dietary assessment tool.^{41,42}

Table 1 presents detailed characteristics and dietary assessment features of the included studies. Participants in nine studies were children under 5 years of age, six studies included WRA, two studies involved school-age children, one included adult women only and one study in an adult population involved predominantly (63%) women participants. Nine studies reported food group intake, four reported nutrient intake and two reported collecting both.

Dietary intake reported in studies that assessed ‘whole diet’ intake in Cambodia

Pooling of absolute dietary intakes by nutrient and/or food group was not possible because of the variability in the data collection and/or reporting and the small

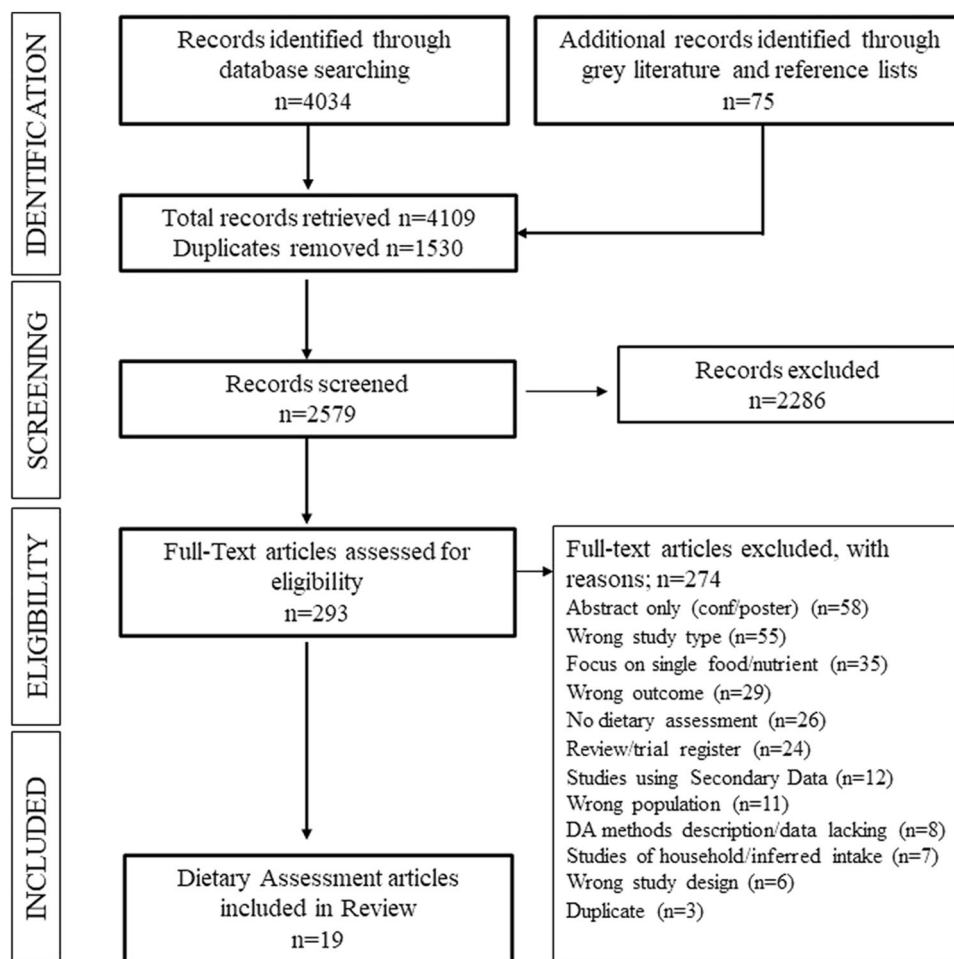


FIGURE 1 PRISMA flow diagram of article identification and inclusion in review of dietary assessment individual-level whole diet studies in Khmer populations living in Cambodia. DA, dietary assessment

representation by each population subgroup. However, a synthesis of the study data is summarised in Table 2.

Intakes spanning 20 nutrients were reported (see Supporting information, Supplementary Tables S1 and S2). Vitamin A and iron were reported in all six studies, with protein, calcium, zinc and energy also commonly reported. Children's reported intakes of vitamin A (151–353 μg RE) and calcium (152–278 mg) varied considerably between studies, whereas macronutrient intakes were fairly consistent between studies. Reported intakes were higher for school-age boys than girls, and inconsistent variability was evident among WRA. In studies that reported dietary or nutrient adequacy, moderate to high proportions of children were inadequate in vitamin A (45%–81%), iron (36%–78%), calcium (76%–99%) and zinc (53%–92%), whereas 50%–89% WRA were inadequate in iron intake.

Eleven studies reported food group intakes, most commonly as amounts in grams or proportion of participants consuming it (see Supporting information, Supplementary Table S3). The number of food groups reported ranged from six to 33. Categorisation of food

groups was inconsistent between studies; for example, vegetable groupings included vitamin A rich vegetables, dark green leafy vegetables, other vegetables, white tubers and roots, or combined fruit and vegetables (see Supporting information, Table S4). Excluding breastmilk for infants, cereals/grains were consistently the most consumed food group by all population groups, followed by flesh foods (such as meats, fish) and vegetables. High intakes of snack foods among children from six months old was evident, whereas younger children reported higher intakes of milk/dairy than school-age children, and WRA intakes varied widely. Fruit intake was moderate across all groups, whereas condiments/spices were a common diet component for WRA.

Of the eight studies of infants, four^{7,32–34,38} accounted for breastmilk intake by applying estimated quantities from World Health Organization,⁴³ according to breastfeeding status (partial or exclusive) and age (up to 12 months only). Bunthang *et al.*³⁷ reported breastfeeding rates for exclusively breastfed infants under 6 months old, although they did not account for the contribution of breastmilk to the nutrient intakes for

TABLE 1 Characteristics and features of included studies for review of dietary assessment studies conducted in Cambodia.

Study Organisation Funding body	Dietary assessment features				Food composition database (FCD)	Quality score
	Population Study type Year DA method	Portion estimation	Administration	Addressing bias/error		
Anderson <i>et al.</i> (2008) University (NZ) University (NZ)	Child < 5 years old <i>n</i> = 251 stunted toddlers 1–4 years old; (15% PBF and 85% NBF), recruited from urban slum village cross-sectional 2003 MP 24 R(1), WFR	<ul style="list-style-type: none"> Food models Calibrated HH measures Weighted portions of rice/fruit/snacks Collected mixed dishes recipes Estimated portion from recipe Estimated BM intake⁴³ 	<ul style="list-style-type: none"> Interview-assisted RA training 	<ul style="list-style-type: none"> List sampling All days of week and weekend represented Used validated 24 R tool⁴⁵ 	<ul style="list-style-type: none"> Specially developed 238-item Thai FCD ASEAN FCD Chemical analyses 	3.0 Reasonable
Bunthang <i>et al.</i> (2014) Royal government of Cambodia University (USA)	Child < 5 years old and WRA/mothers <i>n</i> = 300 mothers with <i>n</i> = 342 child 6–59 months; recruited from 3 rural lake provinces cross-sectional 2014 24 R(1), R-WFR; BFF	<ul style="list-style-type: none"> Real food models Use of standard HH equipment Weighted estimated portions Mother estimated child's portion of shared plate No BM intake included 	<ul style="list-style-type: none"> Interview-assisted RA training 	<ul style="list-style-type: none"> Simple randomised sampling from 3 provinces Recall days not stated Tool pre-tested Data cross-checked 	<ul style="list-style-type: none"> 8 Nutrients: energy, protein, CHO, fats, Fe, Zn, Ca, vit A 13 FGs (g): cereals, sugars/syrups, starchy roots/tubers, fats and oils, fish/OAAs, meat/poultry, eggs, milk products, legumes/nuts/seeds, fruit, veg, beverages, condiments/spices 	3.0 Reasonable
Hanley-Cook <i>et al.</i> (2020) University (Belgium) & FAO German government	WRA <i>n</i> = 430 nonpregnant women 15–49 years old, rural Validation study 2019 WFR versus 24 R(1) (list-based) versus 24 R(1) (open recall)	<ul style="list-style-type: none"> 24 R: portion tool not stated WFR: all food and beverages, recipe ingredients weighed by interviewer Served food for own plate only 	<ul style="list-style-type: none"> Interview-assisted RA training RAs pilot tested Tablets used for data collection 	<ul style="list-style-type: none"> Convenience sampling, sample size calculation Food list adapted to local context Rainy season only Tool pre-tested Randomised 24 R method order Quality checks 	<ul style="list-style-type: none"> 10 FGs (%): all starchy foods, beans/peas, nuts/seeds, dairy, flesh foods, egg, DGLveg, vit A-rich F&V, other veg, other fruit 	5.0 Very good
Horiuchi <i>et al.</i> (2018) University (Japan) and NGO University (Japan)	School-age children <i>n</i> = 2020 children 6–17 years old cross-sectional	<ul style="list-style-type: none"> Standard household measuring units (e.g. bag, cup, dish, spoon, 	<ul style="list-style-type: none"> Interview-assisted RA training 	<ul style="list-style-type: none"> Multistage cluster sampling of schools across Cambodia 	<ul style="list-style-type: none"> 7 Nutrients: energy, protein, CHO, fat, vit A, Fe and Ca 11 FGs (g): staples, legumes/nuts, vegies/ 	3.5 Good

(Continues)

TABLE 1 (Continued)

Study Organisation Funding body	Dietary assessment features				Food composition database (FCD)	Quality score
	Population Study type Year DA method	Portion estimation	Administration	Addressing bias/error		
	2014–2015 24 R (1), FR	slice, bowl, or piece) • Picture book; items and portion sizes • No estimates from shared plate		• Non-normal eating days excluded • Adjusted over/under-reporting	Nutrition Calculation Database 2013	
Horiuchi <i>et al.</i> (2019) University (Japan) and NGO NGO (Japan) ⁴²	School-age children <i>n</i> = 107 children 6–17 years old validation study 2014–2015 24 R(2), FFQ (over 1 month)	• Portion estimates from median of Horiuchi <i>et al.</i> ¹¹	• Interview-assisted • RA training	• Multistage cluster sampling of schools across Cambodia		5.0 Very good
MoH & FIDR (2017) University (Japan) & NGO NGO (Japan) ¹⁸	School-age children <i>n</i> = 2020 children 6–17 years old cross-sectional 2014–2015 24 R(1), FFQ (over 1 month)	• Picture book of 9 food groups; pictures of actual portions sizes; 130 items	• Interview-assisted • RA training • Quality control measures	• Multistage cluster sampling of schools across Cambodia • Calculated sample size • Tool pre-tested		3.5 Good
In <i>et al.</i> (2015) University (Cambodia) not stated ⁹	Adults <i>n</i> = 941 adults 25–65 years old (36% men/64% women); 3 rural and 1 urban areas cross-sectional 2010 24 R(2), FFQ	• Colour photos of 3 different portion sizes • Proportions of shared plate estimated	• Interview-assisted	• Convenient sampling, from 4 regions • Seasonality addressed	• Not stated	3.5 Good
Makurat <i>et al.</i> (2018) University (Germany) German government ³⁶	WRA <i>n</i> = 158 healthy, non-pregnant women factory workers < 31 years old RCT Pre versus Post (5 months) Lunch	• Not stated	• Interview-assisted	• List sample • Simple random allocation to intervention • Calculated sample size	• Not stated	3.0 Reasonable

TABLE 1 (Continued)

Study Organisation Funding body	Dietary assessment features				Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
	Population Study type Year DA method	Portion estimation	Administration	Addressing bias/error			
Menasria <i>et al.</i> (2018) University (Canada), Royal government of Cambodia, NGO NGO (Canada) ³⁴	Child < 5 years old <i>n</i> = 360 infants 6–24 months, excluding severe anemia and malnutrition CRCT, Moringa+NEC versus Cricket+ NEC versus only NEC; 6 months trial Year not stated 24 R(3), BFF	<ul style="list-style-type: none"> Local utensils vitamin and mineral supplements intake collected BM intake (from Dewey & Brown⁴⁴) 	<ul style="list-style-type: none"> Interview-assisted RA training 	<ul style="list-style-type: none"> Cluster random sampling Recall on 2 weekdays + 1 weekend Data checked by 2 RAs Tool pre-tested 	<ul style="list-style-type: none"> 5 Nutrients (satisfaction %): energy, protein, Fe, Zn, vit C 	<ul style="list-style-type: none"> SMILING FCD, ASEAN FCD 	5.5 Very good
NIS/MoH/DHS (USA) (2015) (CDHS 2014) Royal Government of Cambodia Royal government of Cambodia, International aid organisations ⁶	Child <5 years old <i>n</i> = 5120 child <5 years old, subset <i>n</i> = 2836 child <2 years old cross-sectional 2014 24 R(1)	<ul style="list-style-type: none"> Not stated 	<ul style="list-style-type: none"> Interview-assisted RA training 	<ul style="list-style-type: none"> Computerised random sampling Representative sample size Tool pretested Double data entry Data quality checks 	<ul style="list-style-type: none"> 14 FGs (%): infant formula, other milk, other liquid, fortified baby food, food made from grains, vit A-rich F&V, other F&V, food made from roots/tubers, food made from legumes/nuts, meat/fish/poultry eggs, dairy, any semi-solid/solid foods 	<ul style="list-style-type: none"> Not stated 	3.5 Good
Reinbott <i>et al.</i> (2015) Reinbott <i>et al.</i> (2016) (MALIS study) University (Germany) FAO, German government ^{29,30}	Child <5 years old and WRA Pre: <i>n</i> = 743, Post: <i>n</i> = 921 Mothers-infant 6–23-month dyads CRCT, pre post: NEC + agriculture versus agriculture only 2012–2014 Mod FFQ(7), 24 R(1), IFP	<ul style="list-style-type: none"> Not stated 	<ul style="list-style-type: none"> Interview-assisted with primary caregiver RA training Observation 	<ul style="list-style-type: none"> 2-stage probability village sampling and randomised households Tool pretested Quality controls Blinded data entry 	<ul style="list-style-type: none"> 13 FGs (%): grains/roots/white tubers, flesh foods, other F&V; vit A-rich foods, legumes/nuts/eggs, dairy, ASF (meat/fish/poultry/offal), DGL Veg, vit A-rich roots/tubers, vit A-rich fruits, fats/oils, sugary foods/crisps 	<ul style="list-style-type: none"> Not stated 	4.5 Good

(Continues)

TABLE 1 (Continued)

Study Organisation Funding body	Dietary assessment features				Food composition database (FCD)	Quality score
	Population Study type Year DA method	Portion estimation	Administration	Addressing bias/error		
Save the children & USAID (2019) (NOURISH programme) International NGO International aid (USA) ³¹	Child <5 years old and WRA <i>n</i> = 2257 women 15-49 years old (<i>n</i> = 500 WRA; <i>n</i> = 397 pregnant women; <i>n</i> = 405 infant 0-5 months; <i>n</i> = 955 child 6-59 months) Pre and Post, multistratified programme 2018 24 R(1), BFF	• Not stated	• Interview-assisted • Training not stated • Tablets used for data collection (post)	• Random cluster sampling from lists • Calculated sample size proportion to population • Data double translated • Tool pretested • Quality control	• Not stated	3.5 Good
Schümann <i>et al.</i> (2009) University (Germany) German government ³⁵	Child < 5 years old <i>n</i> = 250 infants 6-24 months; excluding severe anemia and acute malnutrition DB-CRCT, Fe + Folate versus Fe + micronutrients versus placebo 2003-2004 FFQ(7) weekly (20 weeks duration)	• Not stated	• Interview-assisted with mother/caregiver • Trained volunteer health workers	• Computer random sampling by village, adjusted for cluster effects • Calculated sample size	• Not stated	5.0 Very good
Skau <i>et al.</i> (2014) University (Denmark), Royal government of Cambodia European Government ³⁸	Child < 5 years old <i>n</i> = 78 infants 6-15 months Cross-sectional Pre and Post RCT: WinFood versus WinFood Lite versus CSB + v CSB + + 2010 24 R(1), R-WFR	• Food pictures • Real food models • Recipe ingredients collected • Weighed estimated portion • Used composite dishes recipes, cooked and weighed (Camb Fish Admin) • BM intake ⁴⁵	• Interview-Assisted • RA training	• List sampling - intervention participants • Recalls on all weekdays • Assumption of over-/under-reporting balance	• USDA FCD • Vietnamese FCD • Thai FCD	2.5 Reasonable

TABLE 1 (Continued)

Study Organisation Funding body	Dietary assessment features				Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
	Population Study type Year DA method	Portion estimation	Administration	Addressing bias/error			
Verbowski <i>et al.</i> (2018) Verbowski (2015) University (Canada), NGO University, NGO, International research centre ^{32,33}	Child <5 years old and WRA <i>n</i> = 421 Child 6 months to 5 years old, <i>n</i> = 429 women 18–50 years old CRCT: Pre and Post, EHFP versus EHFP + F versus no intervention (22 months duration) 2012 Pre: 24 R(1), Post: MP 24 R(2)	<ul style="list-style-type: none"> Common HH items measured Graduated food models F&V: small/medium/large Collected mixed dishes recipe ingredient weights Beverages (ml) Shared plate estimation proportion consumed BM intake⁴³ 	<ul style="list-style-type: none"> Interview-assisted RA training Observed interviews Double recalls for <i>n</i> = 300 subset 	<ul style="list-style-type: none"> Calculated sample size Parallel cluster sampling of RCT participants Separate interviewers repeated 24 R Tool pretested Quality control Double data entry Used 24-VASQ tool (pre); validated 24 R tool⁴⁵ 	<ul style="list-style-type: none"> 14 Nutrients: energy, protein, CHO, fat, Fe, Zn, Ca, vit A, thiamine, riboflavin, niacin, folate, vit B₁₂, water 	<ul style="list-style-type: none"> ASEAN FCD Vietnamese FCD Anderson <i>et al.</i>,⁷ FCD 	4.5 Good
Wallace <i>et al.</i> (2014) University (Canada), International research centre University (Canada) ³⁹	Women/WRA <i>n</i> = 67 women 25–75 years old; excluded unwell cross-sectional + Focus Group 2011 Interactive MP 24 R(1)	<ul style="list-style-type: none"> Not stated 	<ul style="list-style-type: none"> Interview-assisted health workers Training not stated 	<ul style="list-style-type: none"> Convenience sampling from existing programme Alerted participants to note portions consumed before recall Excluded 'non-normal' days Used validated 24 R tool⁴⁵ 	<ul style="list-style-type: none"> 3 Nutrients: energy, Fe, vit A 22 key foods based on Fe and vit A collected, not reported in paper 	<ul style="list-style-type: none"> ASEAN FCD SMILING FCD USDA FCD Thai FCD 	2.0 Poor
Yasuoka <i>et al.</i> (2020) University (Japan) International research centre ⁴⁰	School-age children <i>n</i> = 298 children 6–15 years old, with HIV/AIDS cross-sectional 2018 24 R(1)	<ul style="list-style-type: none"> Not stated 	<ul style="list-style-type: none"> Interview-assisted Training not stated 	<ul style="list-style-type: none"> computer-randomised from list of children receiving HIV treatment 	<ul style="list-style-type: none"> 7 FGs (%): grains/roots/tubers, legumes/nuts, dairy products, flesh foods, eggs, vit A-rich F&V, other F&V 	<ul style="list-style-type: none"> Not stated 	3.0 Reasonable

(Continues)

TABLE 1 (Continued)

Study Organisation Funding body	Dietary assessment features				Dietary intake: nutrients or food groups (FG)	Food composition database (FCD)	Quality score
	Population Study type Year DA method	Portion estimation	Administration	Addressing bias/error			
<ul style="list-style-type: none"> • Tablets used for data collection 							

Abbreviations: 24 R, 24-h recall; 24-VASQ, 24-h vitamin A semi-quantitative; agric, agriculture; ASF, animal source foods; BFF, breastfeeding frequency; BM, breastmilk; CRCT, cluster randomised controlled trial; CSB, corn-soy blend; DGL, dark green leafy (vegetables); DA, dietary assessment; EHFP, enhanced home food production; F&V, fruit and vegetables; FCD, food composition database; FFQ, food frequency questionnaire; FG, food groups; FR, food record; HH, household; I&YC, infant and young children; IFP, infant feeding practices; MP, multiple pass; NBF, nonbreastfed; NEC, nutrition education and counselling; NI, nutrient intake; OAs, other aquatic animals; PBF, partial breastfed; RA, research assistant; R-WFR, retrospective weighed food record; SEA, southeast Asia; WRA, women of reproductive age. *Nutrients*: CHO, carbohydrate; vit A, vitamin A; vit C, vitamin C; Ca, calcium; PO, phosphorus; Na, sodium; K, potassium; Fe, iron; Zn, zinc; Cu, copper.

children over 6 months of age. Reinbott *et al.*^{29,30} and the Save the Children's Nourish project³¹ collected data on breastfeeding practices for measuring intervention effectiveness, and CDHS 2014⁶ collected breastfeeding status and duration data for tracking population behaviour, although there was no reporting of nutrient intakes; hence, they did not apply a breastmilk intake quantification. Schumann *et al.*³⁵ did not consider breastfeeding in their intervention study.

Dietary assessment methods

All but one study ($n = 14$ studies) used 24-h recalls (24 R),^{6,7,9,11,18,29-34,36-42} four studies used food frequency questionnaires (FFQ),^{9,18,29,30,35,42} and five studies reported using another method, including weighed food records (WFR) ($n = 4$)^{7,37,38,41} or food records ($n = 1$).¹¹ Four studies indicated collecting breastfeeding frequency data.^{6,31,34,37} Of the studies that used 24 R, nine conducted a single recall,^{6,7,11,18,29-31,37-40} four collected 2×24 -h recalls^{9,32,33,41,42} and two studies collected 3×24 -h recalls.^{34,36} Four studies indicated using the multipass 24 R method,^{7,32,33,39,41} including a fourth pass to record vitamin and mineral supplements. Hanley-Cook compared a list-based (19 food groups) 24 R against an open recall 24 R method,⁴¹ showing higher intake trends with a list-based method.⁴¹ Three 24 R studies indicated intentional recall days selection, either all days of the week,⁷ only weekdays,³⁸ or scheduled non-consecutive weekdays and a weekend day,³⁴ whereas 'non-normal eating' days were excluded from the data for two studies.^{11,39}

Seven studies combined a 24 R with another method, either FFQ ($n = 3$),^{9,18,29,30,42} WFR ($n = 4$)^{7,37,38,41} or food record ($n = 1$).¹¹ Except for both Horiuchi *et al.*⁴² and Hanley-Cook *et al.*⁴¹ validation studies, these combined methods aimed to enhance the 24 R data collected by adding portion weights (WFR), feeding patterns (observation), frequencies for usual intake or calculating dietary diversity score (DDS).

The reporting period for FFQs varied, with two studies capturing intake from over the past 7 days,^{29,30,35} one over the past month⁴² and one did not specify a reference time.⁹ Only Horiuchi *et al.*⁴² described the FFQ development process, selecting 58 items from 24 R, and 10 frequency categories for all items except rice, which used higher frequency categories.

Three studies^{7,32,33,39} indicated using the validated dietary intake collection tool of Gibson and Ferguson.⁴⁵ Verbowski *et al.*^{32,33} used the 24-h vitamin A semi-questionnaire (24-VASQ) tool of De Pee *et al.*⁴⁶ for baseline, which is not validated. Four studies^{6,31,34,36} indicated that their data collection tool was based on the Cambodian Demographic and Health Survey⁶, which has been pretested and repeatedly used for the national population survey; however, the dietary intake section has not undergone validation and reproducibility testing.

TABLE 2 Synthesis of dietary intake patterns by Khmer population group in dietary assessment study review.

Population group	Nutrient intakes assessed	Food intakes assessed
Child ≤ 5 years	4 studies ^{7,32–34,37} <ul style="list-style-type: none"> All used 24 R, 1³⁴ also collected BFF 7–14 nutrients reported included energy, protein, vitamin A, calcium, iron and zinc Mean energy intake 2678–4067 kJ day⁻¹ Mean protein intake range 17.6–31 g day⁻¹, increasing with age Similar mean intakes for carbohydrate, thiamine, riboflavin and iron across studies Wider range for vitamin A, niacin, calcium and zinc 3 studies^{7,32–34} collected some V&M supps intake 	6 studies ^{6,29–31,35,37,38} <ul style="list-style-type: none"> 5 used 24 R, 2 used FFQ, 2 also used WFR Food groups range of 8–33 Highest intake from grain products and fish Moderate intake of vegetables and snack foods. For children < 2 years included complementary foods, for example, formulated baby foods, infant formula 2 studies^{31,38} included breastmilk as a food item Vit A and iron supp intake reported (CDHS)⁶
School-age children 6–17 years old, male and female	1 study ^{11,18,42} <ul style="list-style-type: none"> Used both 24 R and FFQ Mean energy intake range 5151 kJ day⁻¹ (6-year-old girls) to 8715 kJ day⁻¹ (16–17-year-old boys) Intakes increase with age for vitamin A, iron, calcium, vitamin C and zinc Protein fairly consistent across age groups Boys intakes higher than girls, especially protein and energy Intake from 24 R significantly higher than intake from 58-item FFQ for energy and 4 nutrients 	2 studies ^{11,18,40,42} <ul style="list-style-type: none"> Both used 24 R, 1 also used FFQ MoH & FIDR study¹⁸ reported mean daily intake (g); Yasuoka <i>et al.</i>⁴⁰ % consumption per food group Highest consumption of staples/grains (650 g, 98%), flesh/meat/fish (116 g, 98%), fruit and vegetables (241 g, 72%–81%) High intakes of confectionary (29 g day⁻¹), sugars (14 g day⁻¹) and beverages (89 g day⁻¹) Proportion of daily consumption of junk food (22%) and softdrink (12%); 54% children consume no milk
Women of reproductive age	2 studies ^{32,33,37} <ul style="list-style-type: none"> Both studies used 24 R, 1³⁷ also used WFR, BFF Similar mean nutrient intakes, except carbohydrate Mean energy ranged from 6268 to 8268 kJ day⁻¹ Verbowski <i>et al.</i>³² Verbowski,³³ collected some V&M supps intake at end of study only 	4 studies ^{31,36,37,41} <ul style="list-style-type: none"> All used 24 R, 2 WFR and 2 collected BFF Consistent results; high intake of cereals (369 g), fish (145 g) and vegetables (151 g) Moderate intake of eggs, fruit, beverages Low intake of dairy, white roots, organ meats, legumes/nuts Condiments and fats were prevalent
Adults	1 study ³⁹ (women only) <ul style="list-style-type: none"> Used 24 R Considerably lower medians for vitamin A (249 µg RE) and iron (1.72 mg) than means reported by Bunthang <i>et al.</i>³⁷ and Verbowski <i>et al.</i>,³² Verbowski³³ 	1 study ⁹ (36% men and 64% women) <ul style="list-style-type: none"> Used both 24 R and FFQ Reported 100% participants consume rice daily (average 823 g day⁻¹), over 90% consume vegetables, meat, fish, sugar and condiments. Intakes generally higher for men except fruit, confectionary, condiments Higher intakes of most food items, except beverages in wet season

Abbreviations: 24 R, 24-hour recall; FFQ, food frequency questionnaire; FG, food group; FR, food record; N, nutrient; WFR, weighed food record; BFF, breastfeeding frequency; vit A, vitamin A; V&M supps, vitamin and mineral supplements.

Dietary assessment method features

All studies used an interview-assisted method of data collection. Interviewers were field workers, health workers or research assistants, the majority of whom reported having received training from the primary investigators. All interviewers were local Cambodian people fluent in Khmer language and culture. Thirteen studies used traditional pen-and-paper data collection, and three applied computer-assisted data collections through use of a tablet.^{31,40,41}

Eight studies indicated using at least one tool for estimating portion size. Tools included standard

household utensils volumes ($n = 5$),^{7,11,18,32–34,37,42} food models ($n = 4$)^{7,32,33,37,38} or food photos ($n = 3$).^{9,11,18,38,42} Interviews conducted in participant's home incorporated weighing estimated portions ($n = 5$)^{7,32,33,37,38,41} or calibrated household utensils ($n = 1$).^{32,33} Shared plate eating was addressed by estimating proportion eaten from a given recipe and weighed ($n = 4$).^{9,32,33,37,38}

Randomisation methods included simple randomisation ($n = 1$),³⁷ cluster sampling ($n = 5$),^{11,18,29,30,32–35,42} computer-generated population representation ($n = 1$)⁶ and convenience sampling ($n = 3$),^{9,39,41} with the remaining five studies^{7,31,36,38,40} recruited from lists of

participants from programmes. Table 1 (column 5) reports various techniques for reducing systematic errors for each study, including pre-testing assessment tools ($n = 8$),^{6,11,18,29–34,37,41,42} calculating sample size ($n = 7$),^{6,11,18,31–33,35,36,41,42} and quality control checks during data collection and data entry ($n = 8$).^{6,29–34,36,37,41} Only Horiuchi *et al.*¹¹ reported adjusting for over- and under-reporting. Seasonal differences were accounted for by duration of data collection over both wet (May to October) and dry (November to April) seasons, evident in five studies.^{6,9,11,34,35}

FCDs

Seven studies^{7,11,18,32–34,37–39,42} described using a FCD for calculation of nutrient intakes, whereas eight studies^{6,9,29–31,35,36,40,41} that reported food group consumption patterns did not analyse nutrient intakes and hence did not use FCD. Nine different FCDs were used to calculate nutrient intakes from dietary intake data collected. The ASEAN FCD⁴⁷ (1746-item, 17 food groups, energy and 20 nutrients) was used in six studies,^{7,11,18,32–34,37,39,42} and three studies^{11,18,34,39,42} also used the 90-item SMILING FCD (14 food groups, 19 nutrients, raw ingredients/foods) developed for Cambodia.⁴⁸ Additionally, tailored FCDs were specially developed for three studies^{7,11,18,32,33,42} drawing items from ASEAN FCD, SMILING FCD, Thai FCD, Vietnam FCD, Canada FCD and United States Department of Agriculture (USDA) FCD.

Quality assessment

Critical appraisal of study quality was conducted using the EURRECA tool²⁶ and scores ranged from 2.0 to 5.5 (mean = 3.8, maximum = 7). Four publications achieved the highest quality score of 'very good',^{34,35,41,42} nine were 'good',^{6,9,11,18,29–33} five rated as 'reasonable',^{7,36–38,40} and one was classified as 'poor'.³⁹ All but one publication ($n = 16$) received a score for sample size over 100, and all scored for interviewer-assisted data collection. Less than half the publications accounted for seasonality in their data collection.^{6,9,11,18,34,35} Scores for statistics reflected standard tests for significance, whereas higher scoring publications (>4.5) reported additional statistical analyses. Five publications that measured supplement intake used prompts to assess usage for supplements containing iron, zinc or vitamin A.^{6,7,32–34}

DISCUSSION

Despite three decades focused on improving the health and nutritional status of Khmer people to address poverty-driven malnutrition, only 19 papers (15 studies) have been published on individual-level dietary

assessment data from dietary intake studies in Cambodia. To our knowledge, this review is the first to synthesise published food and nutrient data and characterise dietary assessment methods used in studies that measured the 'whole diet' of Khmer people living in Cambodia. With strong public health policy and non-government organisations focusing on maternal and child nutrition in Cambodia,² it was not surprising that all but one of the included studies were specific to infants, children and women. The dietary assessment methods used to collect dietary intake data were appropriate, but it was not possible to consolidate data because of heterogeneity in outcome measures. Reported food and nutrient intakes of Khmer WRA and children were generally low, although assessing dietary adequacy was not an aim of this review.

Nutrient and food group intake in Cambodia

The low intakes of energy, protein, vitamin A, iron, zinc and calcium reported for both WRA and children across included studies were consistent with findings from studies in other LMICs.^{49,50} Although the nutrient intake data were reasonable within and between studies, synthesis of nutrient data was limited by the heterogeneity in nutrients reported, study characteristics, dietary assessment and statistical analysis methods in the small pool of included studies. Although some nutrient intake variability within and between individuals is expected,⁵¹ some variability could be partly attributable to differences in data collection method, FCD, seasonality, local food supply and preparation methods.⁵² Seasonality as a quality variable reflects the importance of capturing micronutrient differences that vary across seasons, and considering the distinct wet and dry seasons and inadequate nutrient intakes, this is particularly vital for Cambodia. Differences in specific nutrients may also be partly attributable to each study's aims; for example, studies assessing vitamin A intake would specifically measure vitamin A-rich vegetables and fruits groups using the tailored 24-VASQ tool.⁴⁶

Intakes of protein foods, cereals and grains were high and quite consistent between studies, reflecting Cambodia's staple rice, soup and fish diet; however, intakes reported for vegetables, snack foods, foods containing sugar, condiments and beverages were inconsistent. Different classifications of foods into food groups, numbers of 'groups' of foods reported and differing outcomes measuring dietary diversity or specific food item intakes limited comparison of results between studies. Seasonal differences in food intake were reported by In *et al.*,⁹ with higher intakes of rice, starchy roots and vegetables in the wet season, and a higher consumption of all beverages in dry season highlighting the importance of accounting for seasonality in dietary assessment studies. Standardised data collection and reporting of

food groups and nutrients between studies conducted in Cambodia would result in a more robust dietary intake data and facilitate examination of the relationships between diet and health or disease in a range of population groups.

Dietary assessment methodology, methods and study quality

The prominence of the 24-h recall dietary assessment method reflects its versatility for use in different contexts. The standardised data collection approach but open response options are not country-specific, whereas list methods such as a FFQ require considerable adaptation to match country-specific dietary patterns and contexts.²³ Additionally, interviewer-administered 24-h recalls are not literacy-dependent and are less burdensome for the respondent,^{51,53} despite being more time-consuming and resource intensive.²³ It is likely that the use of single-day 24-h recalls contributed to variability of reported dietary intake in included studies, with at least 3 days of dietary intake and a four- or five-stage multiple-pass process recommended for robust data.^{54,55} To further enhance accuracy, multiple-pass methods need modifying to be country-specific, with probes and prompts tailored to the local food culture. Overall, methodological details for 24-h recall and FFQ methods were lacking, which limited data generalisability of study findings.

Portion size estimation tools aim to reduce potentially large measurement errors of quantifying food portions by participants^{52,56}; however, appropriateness and validity of aids also need to be considered for dietary assessment study objectives and participant type.⁵⁷ With all studies except one³⁹ using portion estimation tools that quantified nutrient intake, and the majority using a combination of aids, it would appear the process of estimating portions was appropriate. Individual-level portion estimation is complicated by communal eating, with specific methods to collect dietary intake from shared plates needed for valid intake estimation.²⁰ It is common in Cambodian households for meals to involve multiple people portioning or eating food from one or two central dishes (personal communication). Although shared plate eating was not explicitly reported, studies estimated the proportion consumed from mixed dishes recipes or weighed an estimated portion retrospectively during 24 R.^{7,9,32,33,37} Simple but effective methods for collecting individual-level intake of mixed dishes from shared plates would increase the accuracy of dietary intake estimation in LMIC.²⁰ Other approaches for improving participant recall particularly for LMICs include pre-recall day group training on portion size estimation using picture charts, household items and salted replica food models.^{52,56}

Dietary assessment is prone to systematic errors, including risk of selection bias, observation and recall

biases. Strategies reported in included studies to reduce systematic errors included randomisation methods to reduce selection bias, statistical sampling, varying data collection days, using different interviewers for repeat recalls to mitigate recall bias^{32,33} and excluding days of non-normal intake to reduce risk of analytic errors.^{11,39} Using dietary assessment tools validated for use in the LMIC context is another way to reduce systematic errors in dietary intake data collection.²³ The interactive validated tool for assessing iron and zinc intake used in three included studies was reported as validated for use in developing nations,⁴⁵ although it has not been validated for the Cambodian setting. Although tools such as 24-VASQ⁴⁶ and CDHS⁶ had been pre-tested and adjusted to the Cambodian context, none have been systematically tested and validated against another 'gold standard' method.⁵⁸

Dietary intake data in all included studies were collected by trained local Khmer interviewers. This is likely to have enhanced data quality as personal interviews are reported to increase acceptability to the interviewee and the accuracy and quality of data collected,²⁶ especially when conducted by locals with their intrinsic understanding of cultural food and eating patterns.⁵¹ Although the Food and Agriculture Organization (FAO) recommends that nutritionists and dietitians are preferred field workers in dietary assessment studies,⁵¹ there is limited formal training of nutrition specialists in Cambodia. Until a reputable nutrition-based education programme is established in Cambodia, training suitably skilled Khmer workers to use study-specific tools and administer interviews is more feasible and appropriate than training foreign dietitians to speak Khmer and recognise Cambodia foods, recipes and cooking methods. In this review, quality control measures such as observation, checking data entry and pilot testing were used to increase accuracy and reduce systematic errors were reported in most studies.

The International Network of Food Data Systems (INFOODS)⁵⁹ was established in 1984 to address the need for improved quality and availability of reliable food composition data, but limited investment in FCD in LMICs continues to be a major gap in dietary assessment research.²³ A comprehensive Cambodian-specific FCD was not reported in any studies included in this review, introducing substantial risk of systematic analysis errors. Nutrient data for dietary intake analyses were reported as being sourced from FCDs of other countries, not only primarily South-East Asian, but also Western and European countries. The FCD most accessed was ASEAN, a 1746-item database of foods from five neighbouring Asian countries developed in collaboration with INFOODS.⁴⁷ ASEAN contains very few mixed dishes and no Cambodian-specific foods, and the absence of Khmer translations limits application to Cambodian studies. The versatility of the 90-item Khmer-specific SMILING FCD is limited because it only contains

individual raw ingredients, not cooked foods or mixed dishes.⁴⁸ Studies in this review either used ASEAN only or both of these FCDs but also sourced items from Thai, Vietnamese and USDA FCDs.

This review highlights that the risks of systematic errors in dietary assessment are exacerbated in LMICs, but can be mitigated by adapting evidence-based approaches that suit the cultural context. This was reinforced by the overall ‘good’ study quality rating of included studies, with sample size and interviewer-assisted data collection being well reported. Improvements include accounting for seasonality in data collection, reporting of statistical analysis and reporting of supplementation. The high weighting of supplements in EURRECA reflects their considerable impact on micronutrient intake and EURRECA’s micronutrient focus.^{26,60} The only vitamin or mineral supplement intakes reported in dietary assessment studies in this review were iron,³⁴ vitamin A and zinc supplements for children,⁶ as well as iron supplements for mothers.^{6,31} Supplement intake was likely to be collected in studies that used the multiple-pass method,^{7,32,33,39} but nutrient intakes from supplements were not clearly reported. The quality of reporting and accuracy of micronutrient intake in dietary assessment could be improved if supplement intakes were routinely queried within assessment methods and incorporated, using prompts or probes such as the multiple pass 24 R method.^{54,55}

Limitations

The complexity of accurately assessing and analysing dietary intake at an individual level in Cambodia contributes to some of the limitations reported in this review. It is also likely that the dietary assessment methods and methodologies used in studies may have been rigorous but were not fully or explicitly reported in articles. Additional limitations are attributable to broader societal and socio-demographic Khmer traits. For example, Khmer people may misreport dietary intake if they feel shame about eating certain foods or perceive that their reported food intake will influence taxation or provision of food supplies. Customs such as fasting, food taboos, farming duties and seasonal differences impact data collection planning and process. Local food habits such as foraging, use of medicinal and home-grown Cambodian foods and unique cultural recipes impact on selection of appropriate items from FCDs. These limitations need to be considered and accounted for, where possible, in dietary assessment research in Cambodia and other LMICs.⁵⁸

There are no tailored tools for measuring quality of dietary assessment studies conducted in LMICs, despite quality being identified as problematic.²⁴ The EURRECA study quality assessment tool chosen for this review was selected from five possible tools scrutinised for

suitability. Tools were excluded if they were designed for interventions only⁶¹, were for FFQs only⁶², were reporting on guidelines or were not recommended for appraising quality.^{25,63} Although the three-step EURRECA tool was designed for validation studies, it was determined that step one, consisting of scoring five variables, could be applied to non-validation dietary assessment studies as an indication of quality. The lack of suitable quality assessment tools for dietary assessment studies highlights an opportunity to develop one through expanding EURRECA to add variables such as tool pretesting, reference to a recognised FCD, study duration, quality control measures and intake outcomes reported. This comprehensive description of the methodology would allow for study reproducibility and consolidation of data. A draft checklist in the Supporting information (Table S5) collates variables from these tools as a suggested resource, requiring thorough testing and validating in order to recommend it as a reliable tool.

Implications for future research

The current review has identified priority areas for further research and development to facilitate improved nutrition surveillance, policy planning and promotion in Cambodia. With assistance from international dietary assessment research groups, these recommendations include:

1. Develop a best practice protocol for conducting dietary assessment studies that is appropriate for the Cambodian context with the first step being to review current guidelines for conducting dietary assessment studies from reputable sources,^{45,51,53,55,58,64} then making adjustments for the specific cultural context in Cambodia. A companion checklist for assessing quality of future studies could also be developed.
2. Establish a core minimum data set for reporting dietary intake, including data that are accessible to the wider Asian and international community. Referring to STROBE-nut guidelines would improve standards of reporting,²⁵ and FAO/WHO’s Global Individual Food Consumption Tool (GIFT) would address data access.⁶⁵
3. Establish a Cambodian-specific FCD or expand the existing ASEAN FCD to include commonly consumed food items from different Asian countries or cuisine types, particularly mixed dishes and fortified condiments and sauces.
4. Train and support a workforce of local nutritionists or nutrition researchers to conduct dietary assessment studies and analyse data at an international standard, at the same time as advocating at a national level for maximum policy impact.
5. Use the resources from points (1) to (4) to establish a national nutrition surveillance programme for all

Cambodian population groups (infants, children, adolescents, pregnant women, men and women adults and older-aged adults). This could be incorporated into the 5-yearly CDHS, along with a substudy for validation of tools of specific population groups or key problem nutrients.

6. Generate opportunities for global agency partners to support (funds and expertise) these high-cost strategic initiatives, collaboratively guiding and building capacity with Cambodian professionals.

CONCLUSIONS

Population dietary and nutrient intakes in Cambodia remain suboptimal despite considerable and intentional efforts, particularly towards improving micronutrient intake and preventing malnutrition. This review has identified that global agencies with international dietary assessment expertise need to align or partner with government policy and honour country-specific cultural contexts to facilitate collection and analysis of dietary intake data in LMICs such as Cambodia. Individual-level dietary assessment could be strengthened by standardised reporting, use of consistent nutrient and food group measures, developing a Cambodia-specific FCD, having a competent trained nutrition research workforce, and productive global support and funding. Accurate, specific dietary intake data would inform future nutrition interventions, policy and nutrition surveillance in Cambodia as a key strategy to target improvement in population level nutrition-related health and wellbeing.

AUTHOR CONTRIBUTIONS

Janelle L. Windus is the lead author, primary reviewer, and conducted searches, data extraction and analysis, as well as manuscript preparation and writing. Kerith Duncanson is a secondary reviewer, advising design, data analysis and interpretation, and performed manuscript revision. Tracy L. Burrows is a secondary reviewer, advising design, data analysis and interpretation, and performed manuscript revision. Clare E. Collins is review advisor on design and interpretation, and performed manuscript revision. Megan E. Rollo is a secondary reviewer, advising design, data analysis and interpretation, and performed manuscript revision. All authors contributed to the review design and manuscript drafting, and critically reviewed and approved the final version of the manuscript submitted for publication.

ACKNOWLEDGEMENTS

The authors thank Soriah Harvey and Samantha Stewart for assistance in cross-checking the extraction and quality scoring. This research received no specific grant from any funding agency, commercial or not-for-profit sectors. Megan E. Rollo is supported by funding from

the Hunter Medical Research Institute (Ref HMRI 1661). Open access publishing facilitated by The University of Newcastle, as part of the Wiley - The University of Newcastle agreement via the Council of Australian University Librarians.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

ETHICS STATEMENT

Ethics approval was not required for a review of published studies.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The reporting of this work is compliant with PRISMA guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

ORCID

Janelle L. Windus  <http://orcid.org/0000-0003-0108-9505>

Kerith Duncanson  <http://orcid.org/0000-0001-5525-6589>

Tracy L. Burrows  <http://orcid.org/0000-0002-1431-7864>

Clare E. Collins  <http://orcid.org/0000-0003-3298-756X>

Megan E. Rollo  <http://orcid.org/0000-0003-1303-2063>

REFERENCES

1. Public Health Development. Profile of health and its determinants in Cambodia. United Kingdom: NHS South Central Strategic Health Authority; 2008.
2. Council for Agriculture and Rural Development (CARD) and Technical Working Group for Social Protection and Food Security and Nutrition. The second national strategy for food security and nutrition 2019-2023. Phnom Penh, Cambodia: Ministry of Health; 2019.
3. Asian Development Bank. Cambodia country poverty analysis - December 2011. Philippines: Asian Development Bank; 2012.
4. Roos N, Ponce MC, Doak CM, Dijkhuizen M, Polman K, Chamnan C, et al. Micronutrient status of populations and preventive nutrition interventions in South East Asia. *Matern Child Health J.* 2019;23:29-45. <https://doi.org/10.1007/s10995-018-2639-2>
5. McDonald CM, McLean J, Kroeun H, Talukder A, Lynd LD, Green TJ. Correlates of household food insecurity and low dietary diversity in rural Cambodia. *Asia Pac J Clin Nutr.* 2015;24:720-30. <https://doi.org/10.6133/apjcn.2015.24.4.14>
6. National Institute of Statistics. Cambodian Demographic & Health Survey (CDHS) 2014; included Cambodian Micronutrient Survey (CMNS-2014). Phnom Penh, Cambodia: Ministry of Health, Cambodia; 2015.
7. Anderson VP, Cornwall J, Jack S, Gibson RS. Intakes from non-breastmilk foods for stunted toddlers living in poor urban villages of Phnom Penh, Cambodia, are inadequate. *Matern Child Nutr.* 2008;4:146-59. <https://doi.org/10.1111/j.1740-8709.2007.00120.x>

8. Kuong K, Tor P, Perignon M, Fiorentino M, Chamnan C, Berger J, et al. Multi-micronutrient fortified rice improved serum zinc and folate concentrations of Cambodian school children. A double-blinded cluster-randomized controlled trial. *Nutrients*. 2019;11:2843. <https://doi.org/10.3390/nu1122843>
9. In S, Lambre C, Camel V, Ouldeltkhim M. Regional and seasonal variations of food consumption in Cambodia. *Mal J Nutr*. 2015; 21:167–78.
10. National Institute of Statistics. Food security trend analysis report; Cambodia Socio-Economics Surveys (CSES) 2004 & 2009. Phnom Penh, Cambodia, Ministry of Planning; 2011.
11. Horiuchi Y, Kusama K, Kanha S, Yoshiike N, FIDR research t. Urban-rural differences in nutritional status and dietary intakes of school-aged children in Cambodia. *Nutrients*. 2018;11:14. <https://doi.org/10.3390/nu11010014>
12. Helen Keller International Cambodia. An overview of nutrition sector activities in Cambodia. Phnom Penh: Helen Keller International; 2002.
13. Windus JL, Burrows TL, Duncanson K, Collins CE, Rollo ME. Scoping review of nutrition intervention and dietary assessment studies in Khmer populations living in Cambodia. *J Hum Nutr Diet*. 2021;34:953–68. <https://doi.org/10.1111/jhn.12932>
14. National Nutrition Program. National nutrition strategy: 2009–2015. Phnom Penh, Cambodia: Ministry of Health; 2009.
15. National Nutrition Program. Fast track road map for improving nutrition: 2014–2020. Phnom Penh, Cambodia: National Maternal and Child Health Centre, Ministry of Health; 2014.
16. The World Bank. Cambodia Nutrition Project (P162675). World Bank Group; 2019.
17. United Nations. United Nations sustainable development goals. UN; 2015 [cited 2021 Jul 12]. Available from: <https://sdgs.un.org/>
18. Ministry of Health, National Nutrition Program, and Foundation of International Development Relief (FIDR). Development of recommended dietary allowance and food based dietary guidelines for school aged children in Cambodia. Phnom Penh, Cambodia. 2017.
19. Burlingame B. GEMS/food total diet studies: report of the 2nd International workshop on Total Diet Studies. Brisbane, Australia: World Health Organisation; 2002.
20. Burrows T, Collins C, Adam M, Duncanson K, Rollo M. Dietary assessment of shared plate eating: a missing link. *Nutrients*. 2019; 11(4):789. <https://doi.org/10.3390/nu11040789>
21. deBruyn J, Ferguson E, Allman-Farinelli M, Darnton-Hill I, Maulaga W, Msuya J, et al. Food composition tables in resource-poor settings: exploring current limitations and opportunities, with a focus on animal-source foods in sub-Saharan Africa. *Br J Nutr*. 2016; 116:1–11. <https://doi.org/10.1017/S0007114516003706>
22. Hulshof P, Doets E, Seyha S, Bunthang T, Vongklokham M, Kounnavong S, et al. Food composition tables in Southeast Asia: the contribution of the SMILING project. *Matern Child Health J*. 2019; 23(Suppl 1):46–54. <https://doi.org/10.1007/s10995-018-2528-8>
23. Coates JC, Colaiezzi BA, Bell W, Charrondiere UR, Leclercq C. Overcoming dietary assessment challenges in low-income countries: technological solutions proposed by the International Dietary Data Expansion (INDDEx) Project. *Nutrients*. 2017;9(3):289. <https://doi.org/10.3390/nu9030289>
24. Glasziou P, Altman DG, Bossuyt P, Boutron I, Clarke M, Julious S, et al. Reducing waste from incomplete or unusable reports of biomedical research. *Lancet*. 2014;Jan 18;383:267–76. [https://doi.org/10.1016/S0140-6736\(13\)62228-X](https://doi.org/10.1016/S0140-6736(13)62228-X)
25. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, et al. I. Strengthening the reporting of observational studies in epidemiology – nutritional epidemiology (STROBE-nut): an extension of the STROBE statement. *Nutrition Bulletin*. 2016;41: 240–51. <https://doi.org/10.1111/nbu.12217>
26. Serra-Majem L, Frost Andersen L, Henríque-Sánchez P, Doreste-Alonso J, Sánchez-Villegas A, Ortiz-Andrelluchi A, et al. Evaluating the quality of dietary intake validation studies. *Br J Nutr*. 2009;102:S3–9. <https://doi.org/10.1017/S0007114509993114>
27. den Hartog AP, vanStaveren WA, Brouwer ID. Food habits and consumption in developing countries: manual for field studies. Wageningen, the Netherlands: Wageningen Academic Publishers; 2006.
28. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med*. 2018;169: 467–73. <https://doi.org/10.7326/M18-0850>
29. Reinbott A, Kuchenbecker J, Herrmann J, Jordan I, Muehlhoff E, Kevanna O, et al. A child feeding index is superior to WHO IYCF indicators in explaining length-for-age Z-scores of young children in rural Cambodia. *Paediatr Int Child Health*. 2015;35:124–34. <https://doi.org/10.1179/2046905514Y.0000000155>
30. Reinbott A, Schelling A, Kuchenbecker J, Jeremias T, Russell I, Kevanna O, et al. Nutrition education linked to agricultural interventions improved child dietary diversity in rural Cambodia. *Br J Nutr*. 2016;116:1457–68. <https://doi.org/10.1017/S0007114516003433>
31. Save the Children & USAID. NOURISH project endline survey report. Phnom Penh: Save the Children & USAID; April 2019.
32. Verbowski V, Talukder Z, Hou K, Sok Hoing L, Michaux K, Anderson V, et al. Effect of enhanced homestead food production and aquaculture on dietary intakes of women and children in rural Cambodia: a cluster randomized controlled trial. *Matern Child Nutr*. 2018;14:e12581. <https://doi.org/10.1111/mcn.12581>
33. Verbowski VC. *The effect of plant-based homestead food production with and without small-scale aquaculture on dietary intake of women farmers and their children in Prey Veng, Cambodia (thesis)* [Degree of Master of Science]. Vancouver: University of British Columbia; 2015.
34. Menasria L, Blaney S, Main B, Vong L, Hun V, Raminashvili D, et al. Mitigated impact of provision of local foods combined with nutrition education and counseling on young child nutritional status in Cambodia. *Nutrients*. 2018;10(10):1450. <https://doi.org/10.3390/nu10101450>
35. Schümann K, Longfils P, Monchy D, vonXylander S, Weinheimer H, Solomons NW. Efficacy and safety of twice-weekly administration of three RDAs of iron and folic acid with and without complement of 14 essential micronutrients at one or two RDAs: a placebo-controlled intervention trial in anemic Cambodian infants 6 to 24 months of age. *Eur J Clin Nutr*. 2009; 63:355–68. <https://doi.org/10.1038/sj.ejcn.1602930>
36. Makurat J, Kretz EC, Wieringa FT, Chamnan C, Krawinkel MB. Dietary diversity in Cambodian garment workers: the role of free lunch provision. *Nutrients*. 2018;10(8):1010. <https://doi.org/10.3390/nu10081010>
37. Bunthang T, Nam S, Phen C, Chhantana P, Net E. Enhancing food security and household nutrition of women and children with a focus on nutrient dense commonly consumed fish from capture fisheries and aquaculture in Cambodia, part I. Food and nutritional consumption survey: women and preschool-age children in Cambodia. *Enhanced Trade and Investment for Global Fishery Markets*. 2014;22–50.
38. Skau JK, Bunthang T, Chamnan C, Wieringa FT, Dijkhuizen MA, Roos N, et al. The use of linear programming to determine whether a formulated complementary food product can ensure adequate nutrients for 6- to 11-month-old Cambodian infants. *Am J Clin Nutr*. 2014;99:130–8. <https://doi.org/10.3945/ajcn.113.073700>
39. Wallace LJ, Summerlee AJ, Dewey CE, Hak C, Hall A, Charles CV. Women's nutrient intakes and food-related knowledge in rural Kandal province, Cambodia. *Asia Pac J Clin Nutr*. 2014;23:263–71. <https://doi.org/10.6133/apjcn.2014.23.2.02>
40. Yasuoka J, Yi S, Okawa S, Tuot S, Murayama M, Huot C, et al. Nutritional status and dietary diversity of school-age children

- living with HIV: a cross-sectional study in Phnom Penh, Cambodia. *BMC Public Health*. 2020;20:1181.
41. Hanley-Cook GT, Tung JYA, Sattamini IF, Marinda PA, Thong K, Zerfu D, et al. Minimum dietary diversity for women of reproductive age (MDD-W) data collection: validity of the list-based and open recall methods as compared to weighed food record. *Nutrients*. 2020;12:2039.
 42. Horiuchi Y, Kusama K, Sar K, Yoshiike N. Development and validation of a food frequency questionnaire (FFQ) for assessing dietary macronutrients and calcium intake in Cambodian school-aged children. *Nutr J*. 2019;18:11. <https://doi.org/10.1186/s12937-019-0437-3>
 43. Brown K, Dewey K, Allen L. Complementary feeding of young children in developing countries: a review of current scientific knowledge. Geneva: World Health Organization; 1998.
 44. Dewey KG, Brown KH. Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. *Food & Nutr Bull*. 2003;24(1).
 45. Gibson RS, Ferguson EL. An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries. Harvest Plus. Washington DC: International Life Sciences Institute; 2008.
 46. De Pee S, Bloem MW, Halati S, Soekarjo D, Sari M, Martini E, et al. 24-VASQ method for estimating vitamin A intake: reproducibility and relationship with vitamin A status. Report of the XIX International vitamin A Consultative Group meeting. Washington, DC: International Life Sciences Research Foundation; 1999.
 47. Institute of Nutrition, Mahidol University ASEAN food composition database, Electronic version. 2014 [cited 2021 Aug 6]. Available from: http://www.inmu.mahidol.ac.th/aseanfoods/composition_data.html
 48. Sok SSMILING food composition table for Cambodia. Phnom Penh: Ministry of Agriculture, Forestry and Fisheries of Cambodia, Department of Fisheries Post-Harvest Technologies and Quality Control, Ministry of Health, Cambodia and National Maternal and Child Health Centre; 2013.
 49. Ratsavong K, vanElsacker T, Doungvichit D, Siengsounthone L, Kounnavong S, Essink D. Are dietary intake and nutritional status influenced by gender? The pattern of dietary intake in Lao PDR: a developing country. *Nutr J*. 2020;19(1):31. <https://doi.org/10.1186/s12937-020-00545-9>
 50. Lee SE, Talegawkar SA, Merialdi M, Caulfield LE. Dietary intakes of women during pregnancy in low- and middle-income countries. *Public Health Nutr*. 2013;16:1340–53. <https://doi.org/10.1017/S1368980012004417>
 51. Food and Agriculture Organization of the United Nations. A resource guide to method selection and application in low resource settings. Rome, Italy: Food and Agriculture Organization of the United Nations; 2018.
 52. Gibson R, Charrondiere UR, Bell W. Measurement errors in dietary assessment using self-reported 24-hour recalls in low-income countries and strategies for their prevention. *Adv Nutr*. 2017;8:980–91. <https://doi.org/10.3945/an.117.016980>
 53. Institute of Medicine. Dietary risk assessment in the WIC program. Washington, DC: Committee on Dietary Risk Assessment in the WIC Program; 2002.
 54. Steinfeldt L, Anand J, Murayi T. Food reporting patterns in the USDA automated multiple-pass method. *Procedia Food Sci*. 2013;2:145–56. <https://doi.org/10.1016/j.profoo.2013.04.022>
 55. Gibson RS. Principles of nutrition assessment. 2nd ed. New York: Oxford University Press; 2005.
 56. Sharma V, Chadha R. Effectiveness of food portion size estimation aids for diet assessment: A systematic review. *Int J Food Sci Nutr Diet*. 2017;2:106–12.
 57. deVlieger NM, Weltert M, Molenaar A, McCaffrey TA, Rollo ME, Truby H, et al. A systematic review of recall errors associated with portion size estimation aids in children. *Appetite*. 2020;147:104522. <https://doi.org/10.1016/j.appet.2019.104522>
 58. Cameron ME, Van Staveren WA. Manual on methodology for food consumption studies. Oxford: Oxford University Press; 1988.
 59. International Network of Food Data Systems (INFOODS). FAO. [2021 cited Oct 02]. Available from: www.fao.org/infoods
 60. Henriquez-Sánchez P, Sánchez-Villegas A, Doreste-Alonso J, Ortiz-Andrellucchi A, Primer K, Serra-Majem L. Dietary assessment methods for micronutrient intake: a systematic review on vitamins. *Br J Nutr*. 2009;102: S10–37. <https://doi.org/10.1017/S0007114509993126>
 61. Academy of Nutrition and Dietetics. Evidence analysis manual: steps in the academy evidence analysis process. Chicago, USA: Academy of Nutrition and Dietetics; 2016.
 62. Dennis LK, Snetselaar LG, Nothwehr FK, Stewart RE. Developing a scoring method for evaluating dietary methodology in reviews of epidemiologic studies. *J Am Diet Assoc*. 2003;103: 483–7. <https://doi.org/10.1053/jada.2003.50081>
 63. Schulz KF, Altman DG, Moher D, CONSORT Group. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. *BMC Med*. 2010;8:18. <https://doi.org/10.1186/1741-7015-8-18>
 64. Cade JE, Warthon-Medina M, Albar S, Alwan NA, Ness A, Roe M, et al. DIET@NET: Best Practice Guidelines for dietary assessment in health research. *BMC Med*. 2017;15:202. <https://doi.org/10.1186/s12916-017-0962-x>
 65. Leclercq C, Allemand P, Balcerzak A, et al. FAO/WHO GIFT (Global Individual Food consumption data Tool): a global repository for harmonised individual quantitative food consumption studies. In: *Proc Nutr Soc*. 78. 2019. p. 484–95. <https://doi.org/10.1017/S0029665119000491>

AUTHOR BIOGRAPHIES



Mrs Janelle L. Windus, BappSci (F&N), MND. Janelle's experience includes hospital and private clinical dietetics, university-based research on pregnancy and infant nutrition programmes, and dietary assessment in Cambodia, on which her current PhD studies is based.



Dr Kerith Duncanson, PhD. Kerith's diverse career includes 30 years of nutrition and dietetics across public and private sectors and Research Dietitian for University of Newcastle, with her PhD investigating child feeding practices.



Professor Tracy L. Burrows, PhD. Tracy is a Professor in Nutrition and Dietetics at University of Newcastle and researcher at Hunter Medical Research Institute, focusing on dietary assessment, eating behaviors, weight management and addictive eating.



Laureate Professor Clare E. Collins, PhD. Clare is a Fellow of the Australian Academy of Health and Medical Sciences, Nutrition Society of Australia and Dietitians Australia. Her research focusses on personalised nutrition technologies/programmes evaluating impact on diet-related health across life stages and chronic disease.



Dr Megan E. Rollo, PhD. As Research Fellow in Nutrition and Dietetics within the School of Health Sciences at University of Newcastle, Megan has investigated technology-assisted dietary assessment and personalised behavioral nutrition interventions.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Windus JL, Duncanson K, Burrows TL, Collins CE, Rollo ME. Review of dietary assessment studies conducted among Khmer populations living in Cambodia. *J Hum Nutr Diet.* 2022;35:901–918.
<https://doi.org/10.1111/jhn.13011>