Systematic Review

Measuring dietary intake in low-and middle-income countries: a systematic review of the methods and tools for estimating fish and seafood intake

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Context: *Fish and seafood consumption makes an important but often under-recognized contribution to dietary patterns and nutrition, particularly in low- and middle-income countries (LMICs). Therefore, valid, and reliable dietary assessment tools (DATs) and methods to measure seafood consumption in resource-poor settings are needed.* ***Objective:*** *To review the available DATs that have been used to measure fish and seafood consumption in LMICs and to assess their quality.* ***Data sources:*** *A systematic search of the electronic databases Scopus, Embase, and Medline was conducted, identifying 1541 initial articles, of which 122 eligible full-text articles were reviewed.* ***Data extraction:*** *Data extraction focused on the purpose of dietary assessment, setting, target population group, DAT type, administration mode, type of fish and seafood assessed, specific measure of food intake, use of a portion-size-estimation aid, and details of validity, reliability, and pilot testing of the DATs.* ***Data analysis:*** *The most common DATs used were food frequency questionnaires (n = 80; 58%), of which 36 (25%) were semi-quantitative. The majority of tools (n = 107; 78%) included measurement of consumption frequency; only 41 studies (30%) measured frequency, quantity, and type of seafood consumed. Only 41 DATs (30%) solely focused on fish or seafood intake. Most DATs were interviewer administered (n = 80; 58%), 23 (16%) mentioned the use of a portion-size-estimation aid, and validity was tested for only 13% of DATs (n = 18).* ***Conclusion:*** *This systematic review reveals a lack of sufficient detail in the use of standard DATs to fully capture the contribution of fish and seafood to diets in LMICs. Consequently, the need to develop or adapt existing DATs to capture frequency, quantity, and type of fish and seafood intake with consideration of cultural eating practices has been highlighted. This is essential for informing appropriate interventions to leverage the nutritional benefits of seafood consumption in LMICs.* ***Systematic Review Registration:*** *PROSPERO registration no.* CRD42021253607.

Key words: *aquatic food, dietary assessment, fish, low- and middle-income countries, seafood.*

INTRODUCTION

Malnutrition is one of the most significant challenges of the modern era, presenting as both overnutrition in the form of overweight or obesity, or undernutrition, which manifests as wasting, stunting, underweight, and micronutrient deficiencies.[1] At present, almost one-third of the global population is affected by at least 1 form of

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malnutrition, with sub-Saharan Africa, South Asia, East Asia, and the Pacific among the most affected regions[2] (regional grouping according to World Bank's regional classification).[3] Vulnerable population groups, which include elderly populations, pregnant and lactating women, adolescent girls, and young children, have a higher risk of suffering from 1 or more forms of malnutrition.[4] Every year, nutrition deficiency–related deaths affect 3.5 million women and children worldwide,[5] and in low- and middle-income countries (LMICs), malnutrition accounts for 45% of deaths among children younger than 5 years, while globally, 22.2% suffer from stunted growth.[1,6]

There is increasing recognition of the important role that fish and seafood consumption plays in combatting malnutrition.[7–12] Globally, extrapolation from fish supply data indicates that fish and seafood provide approximately 17% of consumed animal-food source, and this percentage is even greater in certain LMICs.[13] In 31 countries, of which 21 were classified as low income, fish accounted for more than 30% of animal-food source intake.[14] Furthermore, in many LMICs that have fishery resources, fish plays an essential role in the diets of poor and rural populations, often being considered the preferred animal food source due to its accessibility and affordability.[15] Therefore, despite a lack of detailed data on individual consumption, fish and seafood can be considered a vital food source, contributing to dietary diversity through a unique combination of animal-food source, essential fatty acids, minerals, and vitamins.[7]

Despite the central role that fish and seafood consumption has in addressing the multiple burdens of malnutrition in many regions, there is a lack of data on the dietary patterns of those living in LMICs.[16] Dietary data in LMICs are often limited to household-level food acquisition or questionnaires involving a small sample population in specific geographic areas.[16,17] This is largely due to a lack of resources for the collection of detailed dietary data on a large-population scale.[18,19] Although household surveys, such as nationally representative income and expenditure surveys, provide useful insights into food acquisition patterns, they lack important detail on intra-household food-consumption patterns.[20] In some cultures, women do not have the authority to influence the division of food among family members. Often, adult men are served the most nutritious food first, leaving children and women with inadequate access to food.[21,22] For example, in Zambia and Malawi, the whole fish or fillets are given to the head of the household or the elders while children either receive no fish or seafood or the broth in which the fish or seafood was boiled.[23]

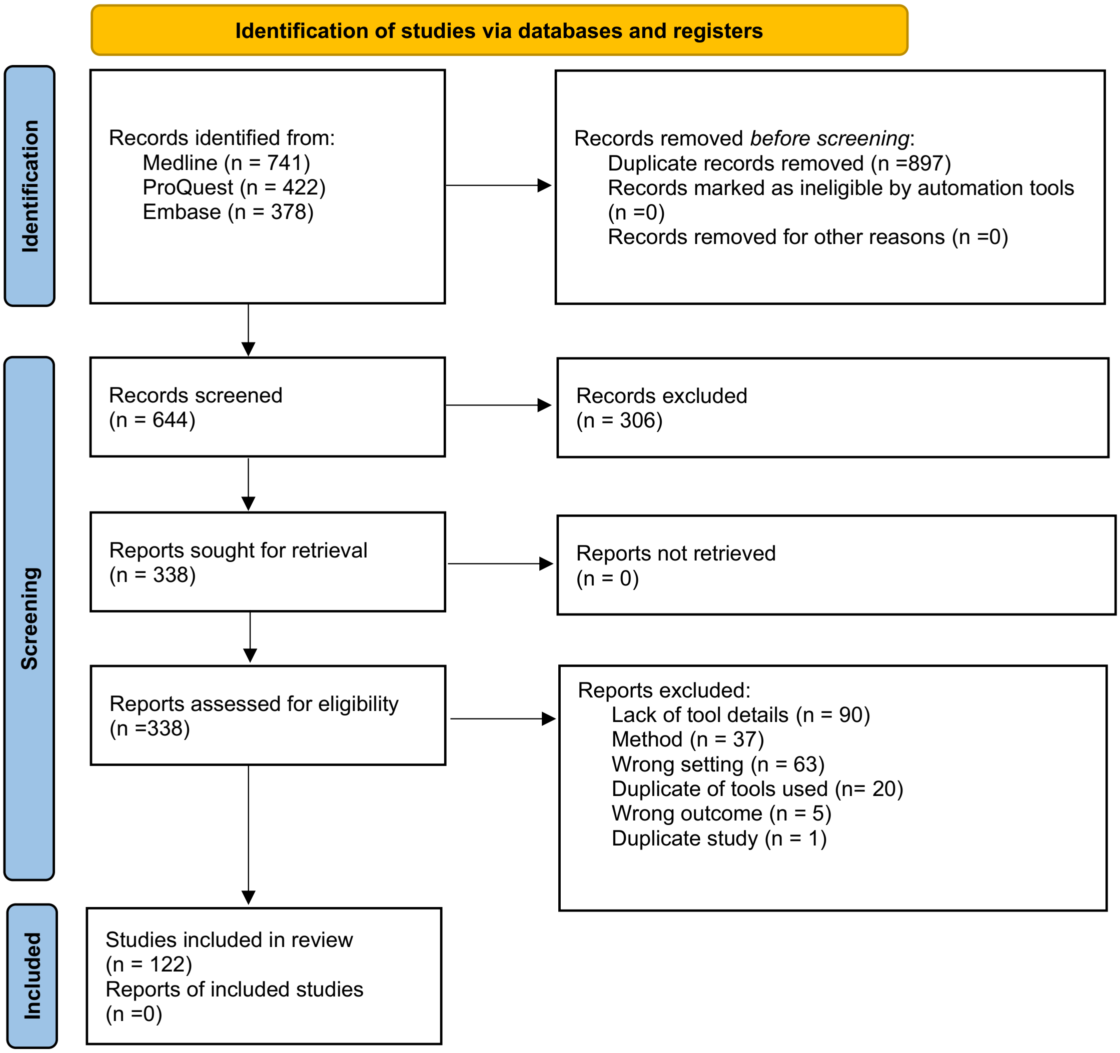
The use of validated and culturally appropriate dietary assessment tools (DATs) is an essential component of being able to obtain accurate data on fish and seafood consumption patterns for individuals. Without such tools, it is difficult to implement tailored interventions and surveillance programs in target populations and, consequently, evaluate interventions that aim to increase fish and seafood intake. The need for such tools in LMICs is particularly pressing relative to high-income countries (HICs), given the high rates of malnutrition,[24] the importance of fish and seafood in the diets of LMIC populations, and the current paucity of data on consumption patterns in these settings,[18] as described. The food availability and consumption patterns, with different traditional foods, cooking methods, and portion sizes, as well as food attitudes and beliefs that can vary greatly between cultures and communities, make it challenging to use common and validated DATs developed for HICs.[16,18] Additionally, some of the common foods found in LMICs may not be included in the food composition databases traditionally used to develop DATs.[18,25] LMICs often have limited resources pertaining to the cost and feasibility of collecting dietary data, such as lack of trained personnel, limited technology and infrastructure, and limited funding for research.[18] Therefore, tools that are affordable and practical to use in these settings are needed. Finally, many LMICs are undergoing a nutritional transition, with diets shifting from traditional, locally grown foods to a more Western-style diet, making it important to have DATs that can capture these changes.[26–29] To accurately assess dietary intake and identify areas for improvement, it is important to use tools that are appropriate for the populations being studied in LMICs.

The objective of this study is to determine how fish and seafood consumption is measured in LMICs in terms of (1) dietary assessment methods, (2) accompanying tools that are used to assist in estimating portion size (eg, visual aids, food models), (3) strengths and weaknesses of the identified tools and methods, and (4) validity and reliability of the identified tools and methods.

METHODS

Search strategy

A systematic literature search was conducted in accordance with the Preferred Items for Reporting in Systematic Reviews and Meta-Analyses (PRISMA)[30] reporting guidelines to identify articles published between 2000 and 2021 that described methods to assess dietary fish and seafood intake in LMICs (Figure 1 and see Table S1 in the Supporting Information online). The search was conducted between April and May



Exclusion guide:

- **Method**: Consumption is not directly measured in the study; for example, a study might use average national trends instead of direct objective measure)
- **Wrong setting:** Settings other than resource-poor settings (lower- and middle-income countries)
- **Wrong outcome**: a study that solely assesses dietary intake from a qualitative lens (eg, perceptions, attitudes).
- **Wrong intervention**: Study does not assess fish/seafood intake
- **Not an empirical study**: articles that do not report on a primary study, such as book chapter, reviews or conference reports
- **Lack of tool details**: Consumption has been measured but there is lack of detail about how it was measured, with no links to the tool used.
- **Duplicate of tools used:** Two studies have used the same dietary assessment tool in the same population. The study that provides more details about the tool used, the population, and/or the validity is selected.

Figure 1 **Flow diagram of the Preferred Items for Reporting in Systematic Reviews and Meta-Analyses (PRISMA) literature search and screening process.**

2021, using the Embase, Scopus, and Medline databases. Each database was searched using keywords related to DATs and methods; fish and seafood; dietary intake and food consumption; vulnerable populations; low-income countries; and middle-income countries (see Table S2 in the Supporting Information online). A protocol was developed in accordance with PRISMA guidelines[30] and registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42021253607).[31] However, final methods used for data extraction deviated from the original protocol, as described below.

Eligibility criteria

Studies were required to meet the following criteria to be eligible for inclusion: (1) full-text, peer-reviewed journal articles published between January 2000 and March 2021 in English; (2) studies that developed, validated, or used a DAT that estimated fish and/or seafood intake; and (3) studies of humans living in 1 of the 176 countries on the 2020 Cochrane Effective Practice and Organization of Care (EPOC) LMIC list.[32] There was no restriction on the study design or studies that used secondary data as long as sufficient details on original methods and tools for data collection were specified. All studies reporting measuring intake were considered for eligibility. Intake measurements included some innovative techniques, such as the use of biomarkers to estimate fish and seafood consumption, because the recent literature is providing growing evidence that numerous markers are being validated for this purpose.[33–35]

Studies were excluded if they reported fish or seafood intake without detailing the following information: the specific DAT that was used, at least 1 measure of fish and seafood intake (eg, intake frequency, amount consumed, and/or type of seafood), and how the tool was administered (eg, interview administered, self-administered). Review articles, non–English language articles, studies published in countries not listed on the Cochrane EPOC list, and studies that used a qualitative method of assessing fish or seafood intake (eg, perception or attitudes toward fish and seafood intake) were also excluded. For DATs that were included in multiple articles related to the same study and same population, only the article providing the most detail about the DAT was included. During the screening phase, the use of the EPOC LMIC country list in the search process returned several results from HICs based on the 2020 World Bank country and lending group classifications.[3] Discrepancies between the 2 lists were determined manually and articles from countries considered HICs according to the 2020 World Bank classification were excluded. The Population, Intervention, Comparison, and Outcome (PICO) criteria for inclusion and exclusion of studies are presented in Table 1.

Study selection

The articles retrieved from the database search were uploaded to Paperpile reference manager[36] and checked for duplicates. After the removal of the duplicates, the remaining records were uploaded to the systematic review manager Colandr.[37] Each of the articles' titles

Table 1 **The PICOS criteria for inclusion and exclusion of studies**

	Inclusion	Exclusion
Population	Human studies based in free-living settings Populations of any age directly exposed to a dietary assessment tool or method	Animal studies
Intervention(s), exposure(s)	Studies including dietary-intake assessment methodology, specifically methods and tools used to assess the intake of seafood	Studies that do not assess fish and seafood intake Studies that do not directly measure intake Studies in which the methodology does not provide enough details about the tool used to assess dietary intake Repeated information from a previously included population
Context	Studies in which the population lives in low- and middle-income countries based on the countries listed on the World Bank 2020 country and lending group classifications	Studies where the population lives in high-income countries
Outcome	Studies assessing quantitative dietary intake	Studies that solely assess dietary intake from a qualitative lens (eg, assessment of preferences, perceptions, attitudes)
Type of publication	Cross-sectional studies Case-control studies Cohort studies Qualitative studies Ecological studies Case reports Experimental studies Articles published between January 2000 and March 2021	Book chapters Conference reports Literature reviews Systematic reviews

and abstracts were screened for inclusion by 2 reviewers (E.M.D.C. and M.M.) independently and conflicts were resolved by consultation between the 2 reviewers. Selected full texts were retrieved and uploaded into Colandr. Full-text screening was conducted by a single reviewer using Colandr (the total number of papers was divided equally between 2 reviewers, E.M.D.C. and M.M.). To ensure consistency, 10% of articles were randomly selected and cross-checked by both reviewers and no conflicts were observed.

Data extraction

The following information was extracted in an MS Excel table: title of the article; first author's surname; publication year; outcome measured in the study; sample size; study design; setting (country and degree of urbanization); participant characteristics (life stage and sex); DAT type; DAT administration mode (eg, interview, self-administered survey, online record); types of food assessed; number of food groups or categories in the tool; measure of fish and seafood consumption; portion-size estimation aid (PSEA); measure of seasonality; and description and details of the assessment of validity, reliability, and pilot testing of the tool. The DAT types were categorized according to standard methods per the United Kingdom Medical Research Council's DAPA Measurement Toolkit[38] (see Table S3 in the Supporting Information online). Tools that could not be categorized under this classification, such as customized questionnaires, focus group questions,[39] or school menu assessment,[40] were labelled as nonstandardized questionnaire (NSQ). Because of the large number of studies that met inclusion criteria, full data extraction was not done in duplicate, as stipulated in the original review protocol. Instead, extraction was completed by a single reviewer, with the studies divided equally between 2 reviewers (E.M.D.C. and M.M.), then extracted data were cross-checked for quality by a second reviewer for 25% of the studies.

Quality assessment

The quality of the DATs was assessed using a modified dietary intake methodology-reporting checklist developed by Burrows et al[41] (see Table S4 in the Supporting Information online). Studies that contained sufficient detail in the methodology section and supporting materials were included for quality assessment. The scoring criterion was modified to include criteria related to assessment of reliability and whether DATs were pilot tested, in addition to the original criteria of validity testing, data-collection quality, scoring methods (weighting or nutrient calculation), as well as specific criteria for the use of food frequency questionnaires (FFQs), recall methods, diet histories, and dietary questionnaires. To accommodate the additional criteria, the scoring system was also adapted such that the maximum score was 8.5. The quality of the DAT was determined using the following coding method: excellent ($\geq$6); good ($\geq$4 and < 6); acceptable/reasonable ($\geq$2.5 and < 4); and poor ($\leq$ 2 points).

RESULTS

In total, 1541 articles were identified in the initial database search, of which 122 articles met the inclusion criteria for this review (Figure 1) and 21 articles contained sufficient detail for quality assessment. The most common reasons for exclusion (n = 216) at the full-text review stage were a lack of detail about the DAT used (n = 90; 42%), studies observing populations not in free-living settings in the specified LMICs (n = 63; 29%), and studies that did not directly quantify fish or seafood intake (n = 37; 17%) (Figure 1).

Study characteristics

The main types of study designs included cross-sectional studies (n = 85; 69%), followed by cohort studies (13; 11%), ecological studies (n = 10; 8%), and case-control studies (n = 7; 6%). The median sample size was highest for 24-hour recalls (median, n = 3206), food diaries (median, n = 1268), semi-quantitative FFQs (SQ-FFQs; median, n = 316) and FFQs (median, n = 191).

The 122 included studies spanned 49 LMICs and 6 global regions as classified by the 2020 World Bank country and lending groups.[3] In terms of regional distribution, Latin America and the Caribbean had the largest number of publications (n = 43; 35%), of which many were set in Brazilian Amazonian communities (n = 15l 12%),[42–56] followed by East Asia and the Pacific (n = 31l 25%), 77% of which were set in China. Central Asia, Africa, and the Middle East were the least represented regions in the included studies. In terms of the degree of urbanization, most studies were either set in urban regions (n = 42l 34%), unspecified (n = 27l 22%) or a mix of regions (n = 22l 18%), with fewer studies taking place in rural (n = 19l 16%) or remote (n = 10, 8%) areas.

Fish and seafood consumption was measured at an individual level for 110 studies (90%) and 8 studies measured food consumption at the household level. Notably, 2 studies examined intra-household consumption,[57,58] and 3 studies investigated food consumption in mother-child pairs.

Most studies included women and men (n = 79; 65%). Twenty-nine studies (24%) focused on women, of which 10 centered on pregnant women and 6 on breast-feeding women. Thirty-one studies (25%) focused on adults, followed by 29 studies (24%) measuring intake for mixed life stages and 16 (13%) that focused on all life stages. Ten studies (12.2%) applied a DAT specifically to children, with 1 specifying children being of complementary feeding age (ages 6–24 months old). The most common tools used in children's studies were FFQs and SQ-FFQs. This is consistent with the types of tools most used in adult populations in this review.

The most common purpose for which DATs were used was to assess human dietary exposure to chemical compounds (n = 55; 45%), specifically mercury, other heavy metals, and organochlorines. Other purposes for using DATs included assessing the impact of different dietary factors, including effects of fish and seafood intake on health outcomes (n = 31 studies; 25%), namely metabolic syndrome, cognitive health, and psychological health; and to assess nutrient intake (n = 18 studies; 15%), dietary patterns (n= 13; 8%), and for validation and DAT development studies (n = 9; 5%). FFQs and SQ-FFQs were primarily used to assess chemical compound exposure and health outcomes, and 24-hour recalls were consistently used across different study purposes.

Characteristics of dietary assessment tools

A total of 137 DATs were identified in the 122 included studies; 15 studies (12%) used a combination of 2 tools. The most common tool used in the included studies was the FFQ (n = 80; 58%), including 36 SQ-FFQs. Eighteen studies (13%) used 24 hour recall (including 13 quantitative recalls), 6 (4%) used biomarkers (eg, fatty acid, mercury, taurine) to measure fish and seafood consumption, 4 (3%) used weighed-food records, 3 (2%) used a food diary, and 2 (1%) used direct observation (Figure 2). Fifteen studies used a combination of 2 DATs, with the most common combination being 24-hour recalls with FFQs (n = 5), and 24 studies (18%) used NSQs. The NSQs were developed to suit the various objectives of individual studies; thus, the level of detail elicited in the questionnaires was highly variable. One questionnaire[54] only included 1 question: "What is the fish species you most frequently consumed during the year?" Another questionnaire[59] captured multiple variables by asking participants about the number of fish meals consumed in the prior 3 days, whether participants consumed a variety of 27 local fish species, the methods of fish preparation, and the source of acquisition of the fish (eg, market, river, ocean).

The majority of tools collected data through interviewer-administered questionnaires (n = 80; 58%), followed by self-administered surveys (n = 13; 9%). Notably, 2 studies used technology to collect data online. Of these, 1 used an interviewer-administered survey through the Kobo toolbox app[60] and the other used a self-administered online survey sent through social media.[61] Additionally, 1 study used a combination of interviews and a self-administered survey, 1 used supervised weighing and recording of intake, and

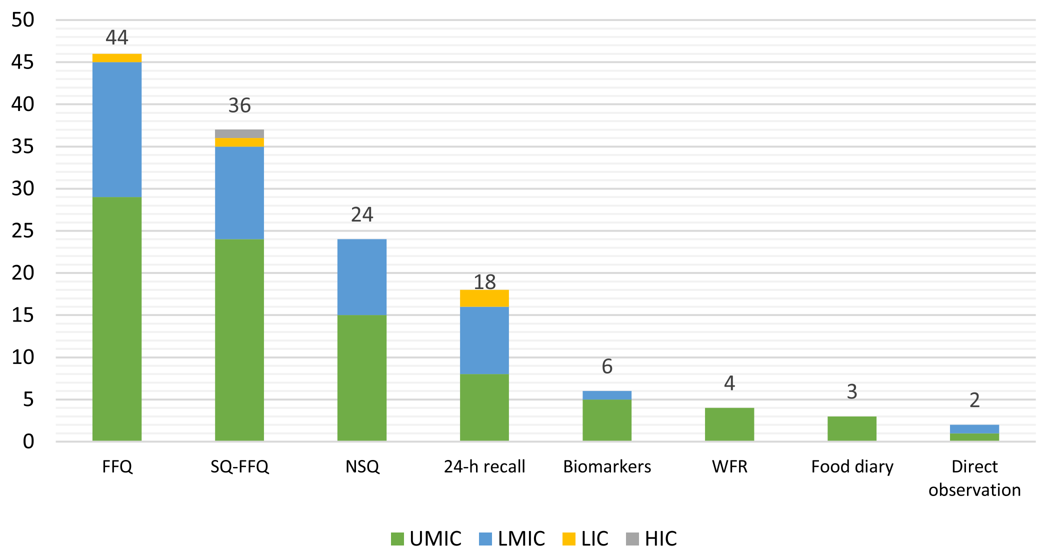


Figure 2 **Types of dietary assessment tools identified in the literature (n = 137).**

The total number of dietary assessment tools (n = 137) exceeds the number of included studies (n = 122) because some studies used multiple tools. *Abbreviations:* FFQ, food frequency questionnaire; NSQ, nonstandard food frequency questionnaire; SQ-FFQ, semi-quantitative food frequency questionnaire; WFR, weighed-food record.

1 used hair-sample collection.[43] Finally, in 26 of the included DATs (19%), the administration method to collect dietary data was not specified.

Most of the 18 examined 24-hour recalls were administered once (n = 13; 72%); however, some studies used multiple recalls including 3,[62–64] 5,[17] and 10[65] consecutive days. No FFQs were administered more than once. An average week within the context of the preceding year was the most common way to conceptualize consumption frequency of fish and seafood consumption (eg, frequency of fish and seafood consumption during the last year, as categorized by ≥ 4 times/week, 1–3 times/week, or < 1 time/week). A small number of included tools (n = 13; 9%) accounted for seasonality in their measure of fish and seafood consumption, either by asking about consumption of certain food items across specific seasons[66–68] or selectively performing the questionnaire within a specific season.[69–71] Of these, 4 were SQ-FFQs, 3 were 24-hour recalls, 3 were NSQs, and 3 were FFQs. Additionally, only a 2 studies (1%) reported having developed a food list that was specifically designed for the target population of the study.

In terms of the number of food items and categories included in the tool, fish and seafood specific FFQs comprised, on average, 4 categories (range, 1–15) or 54 individual items (range, 4–170), whereas FFQs that assessed total diet included, on average, 8 categories (range, 1–21) or 99 food items (range, 59–168). About half of the FFQ included in this review assessed quantity (weight or portion size) as well as frequency (eg, how often a determined portion has been eaten). Only one-third accounted for frequency, quantity, and type of fish and seafood, and only 9 of these were reported to have been validated for the specific context.

The majority of tools (n = 107; 78%) included frequency of consumption as a measure of fish and seafood intake. Forty DATs (29%) measured frequency, quantity, and type of fish or seafood. Forty-nine tools (36%) used 2 forms of measurement, with 23 DATs measuring both frequency and type, 17 measuring frequency and quantity, and 9 measuring quantity and type. Finally, 33 tools (24%) used only 1 measure of consumption, with 27 measuring frequency only and 6 focusing on quantity.

In most included tools, multiple food items were measured (n = 79; 57%). Some focused on fish only (n = 29; 21%), and others included all seafood (n = 14; 10%).

The details about the type of fish and seafood measured included sub-classification within the fish and seafood category (eg, fish, shellfish, mollusks, crustaceans; n = 12); distinction between farmed and wild-caught fish or seafood (n = 1), freshwater or salt water fish or seafood (n = 2); specific species of fish or seafood (n = 16); mode of preparation (eg, fried, dried, canned; n = 5); size (small, large; n = 7) or a combination of 2 or more (n = 6). Five tools asked open-ended questions about the type of fish, and the 18 remaining papers stated, without specifying details, that the DAT recorded the type of fish.

Of the 74 tools that obtained quantifiable information on dietary intake, only 23 mentioned the use of a PSEA. The majority of these were SQ-FFQs (n = 10; 43%) followed by 24-hour recalls (n = 6; 26%). The main methods to quantify fish and seafood intake included the use of common household measures, food models of fish, and seafood-specific photographs or illustrations of fish commonly eaten in the relevant study setting. Several PSEAs were resourcefully made for the local study population, for example, by using information on fish length to estimate quantity. One study asked participants to use sticks of different lengths to estimate the length of the fish they had eaten, and another used cardboard cutouts of fish of different lengths.[17] In a study conducted in Nigeria, researchers provided a simple weighing scale to 50 households, which worked by balancing stones and dry sand against the weight of the fish. This scale was used by each household every day for 7 months and those data were compared against a 24-hour recall, which was found to have estimated only one-third of the actual fish intake recorded by the scales.[59]

Validity and reliability of DATs

Only 33 studies (27%) reported some validity testing of the used DAT, with criterion validity being the most applied test (n = 8; 24%), followed by content validity (n = 4; 12%), and face validity (n = 2; 6%) (Figure 3A). Only 14 studies (11%) included detail of the reliability of the tools, of which the test/retest (n = 6; 43%) was the most used reliability test, followed by internal consistency (n = 2; 14%) and inter-rater reliability (n = 1; 7%) (Figure 3B).[50] The majority of studies (n = 106; 87%) did not specify if the DAT had been pilot tested. Fourteen studies reported that the tool had been pilot tested, 1 reported the tool had not been so tested, and 1 article was a pilot study for a DAT.

Quality assessment

Twenty-one studies (17%) contained sufficient detail about the tool in either the article, the supplementary material, or a cited validation study to perform a quality assessment (see Table S5 in the Supporting Information online). The majority of the 21 DATs assessed for quality were FFQs (n = 13; 62%), 5 were NSQs (24%), 2

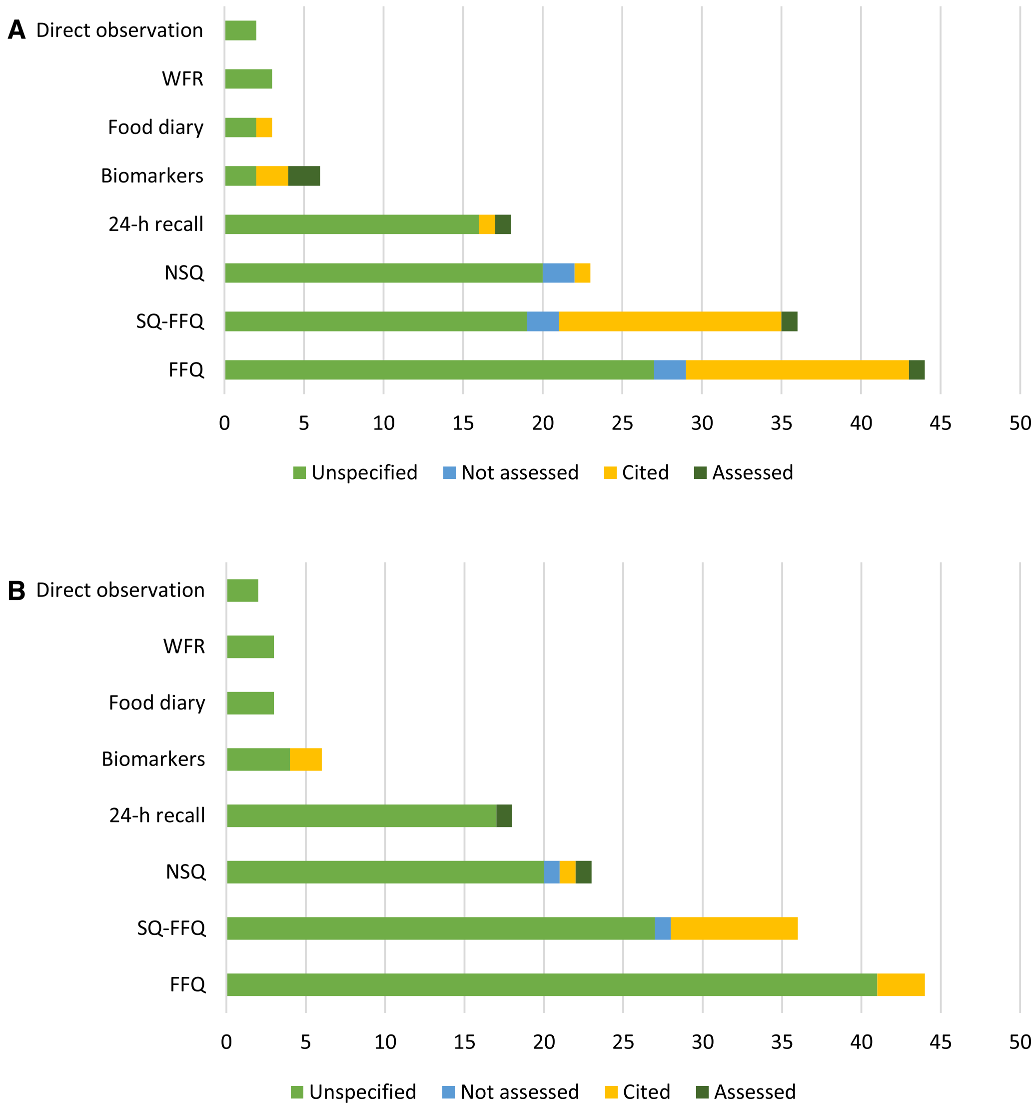


Figure 3 **Bar charts of validity and reliability testing results.**

(A) Validity testing of the dietary assessment tools (n = 137). (B) Reliability testing of the dietary assessment tools (n = 137). The total number of dietary assessment tools exceeds the number of included studies (n = 122) because some studies used multiple tools. *Abbreviations:* FFQ, food frequency questionnaire; HIC, high-income country; LMIC, low- to middle-income country; NSQ, nonstandard food frequency questionnaire; SQ-FFQ, semi-quantitative food frequency questionnaire; UIC, upper-income country; UMIC, upper-middle–income country; WFR, weighed-food record.

were diet recalls (10%), and 1 used a combination of diet history and FFQ (5%). Of the tools assessed, 4 had been tested for validity (20%), 2 had been tested for reliability (10%), and 5 had been pilot tested (24%). Of the tools tested for validity, 2 were tested against weighed-food records, 1 was tested against diet recalls, and 1 used both diet recall and biomarkers for validation. The average quality assessment score was 2.1, which is considered poor, with the scores ranging from 0.5 to 5.5. Only 4 studies referenced or reported a validation study. Most studies (n = 13; 62%) were categorized as having poor quality, 6 DATs (29%) were scored "acceptable" and 2 (10%) were scored "good." None of the assessed tools obtained an excellent score.

DISCUSSION

To our knowledge, this is the first systematic review identifying and collating data about DATs used to measure fish and seafood consumption in LMICs. Seven standard DATs (FFQ, SQ-FFQ, food diaries, weighed-food records, 24-hour recall, direct observation, biomarkers)[38] and an additional 23 nonstandardized DATs emerged from the 122 included studies that spanned 49 countries in 6 regions.

Despite the substantial number of identified DATs, no tool was found to have assessed type, quantity, and frequency of fish and seafood intake with details of validation and reliability in vulnerable populations. Furthermore, most studies lacked details in the descriptions of the type of DAT used and the measurement of dietary fish and seafood intake. This may be because dietary assessment was often not the primary study objective, (eg, chemical exposure studies), and that fish and seafood intake was typically assessed as 1 component of the total diet and was not the focus itself.

The most common DAT identified in this review was the FFQ, which is particularly well suited to estimating episodically consumed foods like fish and seafood.[72,73] Participant burden associated with FFQs is typically low[38] and appears to be further reduced among fish- and seafood-specific FFQs, given the fewer number of items, compared with questionnaires assessing entire dietary intake.

Fish and seafood intake is known to vary across seasons, which has greater implications for some LMICs that rely more on local food production, small-scale fisheries, and aquaculture rather than large-scale commercial fishing that can enable year-round seafood supply.[12,15,74] Despite this, only 4 FFQs and 2 semi-quantitative FFQs reported the inclusion of seasonality in the design and application. Most FFQs were performed once throughout the year, with no details about the season in which the interview took place or the specified recall time frame. This poses a potential bias because determining frequency of intake on the basis of recent memories of consuming specific food items is likely to result in season-specific intake becoming representative of annual consumption.[75]

Because most articles provided minimal detail about the methodology used in the development of the DAT used, it is difficult to ascertain how many DATs were uniquely developed for each study. One indication is that a very small number of studies explicitly reported developing food lists that were tailored to their target population. This highlights the need for more culturally appropriate tools that consider locally available and regionally specific fish and seafood varieties.

The 24-hour recall was the third most-used tool, most of which allowed some quantification of the fish and seafood intake despite only being administered once. The use of a single 24-hour recall, however, is not optimal for assessing usual fish and seafood consumption, because it cannot capture the day-to-day and seasonal variation of a wide variety of fish and seafood species.[37,73,76] It is also likely to underestimate intake, because of the episodic nature of fish and seafood intake.[76,77] Additionally, although less than one-third of the 24-hour recalls were repeated between 3 and 10 times, the repeated days were measured consecutively, which does not allow seasonality to be captured. When designing a DAT using repeated 24-hour recall, researchers should determine a suitable number and frequency of recall measurements by considering both participant and researcher burden as well as monotony or variety of the diet and the diversity of typically consumed fish and seafood.[16,73,78] Moreover, guidelines by the Food and Agriculture Organization and the World Bank for dietary assessment in LMICs[79] recommend performing repeated recalls over 12 months with consideration of seasonality to assess frequency as well as meal participation. These recommendations should be considered when designing DATs.

Several studies used seafood or animal-food source-specific 24-hour recalls, which likely reduced both participant and researcher burden by reducing the total number of items to recall in the past day. However, the error associated with recall bias was still identified in seafood-specific 24-hour recalls. For example, in their validation study, Yokoo et al[80] found that when estimating fish and seafood intake across 3 seasons while using a PSEA, the error was approximately 30% higher when using a 24-hour recall compared to a weighed-food record.

Although several multiple-pass 24-hour recall methods have been validated in LMICs,[81,82] this laborious method was only used in 2 studies.[64,83] Moreover, none of the studies that had sufficient details to complete the quality assessment in this study had used the multiple pass methodology, which contributed to the generally low quality-assessment scores.

Both 24-hour recalls and NSQs were particularly suited to obtaining additional qualitative information. This includes details of local names for certain species of fish and seafood,[84] where fish and seafood were acquired,[65,85–87] typical preparation and cooking methods, as well as traditional recipes and shared eating practices describing the distribution of food inside the household. Such information about cultural and traditional practices in fish and seafood consumption provides important context and details needed to determine accurate fish and seafood intake among different household members. Therefore, it is recommended that tailored qualitative information is captured in addition to, and irrespective of, the type of DAT used.

Although biomarkers were identified in this review, it is important to note that there is conflicting evidence on the reliability of biomarkers to measure total fish and seafood intake.[88–90] Biomarkers are considered the most accurate measure of micronutrient intake;

however, many of these micronutrients are found in a range of food, which makes determining the accurate food source challenging.[91] Nonetheless, some biomarkers seem to allow accurate measure of fish and seafood intake such as eicosapentaenoic acid/docosahexaenoic acid for oily fish or 3-carboxy-4-methyl-5-propyl-2-furanpropionate and trimethylamine *N*-oxide for overall fish consumption.[33] Additionally, methylmercury has also been successfully used to measure fish consumption, and the use of hair samples makes a less invasive and burdensome collection method than biomarkers found in blood or urine samples. However, environmental factors play an important role in the accuracy and applicability of methylmercury as a biomarker for fish consumption, which makes it not suitable for every setting.[92]

More research should be conducted to explore the development of reliable, cost-effective, and noninvasive biomarker measures for fish and seafood intake, as well as improving the validity and reliability of established markers use in LMICs. A noteworthy finding from this review was that DATs were most commonly used to assess human dietary exposure to chemical compounds such as mercury, other heavy metals, and organochlorines. In 2010, the Food and Agriculture Organization and World Health Organization Expert Consultation concluded that the benefits of fish consumption, including reduced risk of coronary heart disease in adults and optimal neurodevelopment in children, outweigh the risks of contaminants such as methylmercury and dioxins.[93] The expert group recommends improved data collection on region-specific nutrients, contaminants, and consumption patterns of fish and seafood. This reinforces the need for valid and reliable DATs and suggests the potential for partnerships between environmental scientists assessing risk exposure and nutrition scientists assessing diet quality to improve the data available in both fields.

Contrary to the trends seen in developed countries, only a few studies used technology-assisted DATs. Barriers such as lack of investment into technological infrastructure, sporadic internet connectivity, and limited access to smartphones or computer devices could explain why paper-based, interviewer-administered DATs were the predominant data collection method identified.[18,19] However, the use of technology such as computers, tablets, and smartphones to assist in dietary assessment has been found to be feasible in lower-income countries,[19] and efforts are being made to increase their use. A notable example is the International Dietary Data Expansion project, which has developed a tablet-based app that can be used to conduct 24-hour recalls and nonstandardized dietary surveys offline, with free access to a global food database. The integration of technology has the potential to enhance dietary assessment in LMICs by reducing participant and researcher burden through greater efficiency with data collection, entry, coding, and analysis.[94,95]

Improving methods of dietary assessment should be done in conjunction with work to enhance food-composition databases to capture a greater diversity of aquatic species as well as more complete micronutrient profiles, particularly those nutrients for which aquatic foods can be a rich source, including vitamin A, vitamin B_{12}, and essential fatty acids. Assessing the quantity of fish and seafood consumed poses unique challenges, given the vast biological diversity of species available for consumption as well as heterogeneity of size, shape, and preparation methods of this diverse food group.[96–98] Household utensils were the most used PSEA, potentially because of participants' familiarity with them and their easy accessibility.[16] The limited research to date suggests that fish- and seafood-specific photographs are a valuable PSEA for LMICs, particularly because they are easier to transport and handle than food models and can accurately depict different cooked seafood portions.[73,97] Although some studies reported using seafood-specific photographs, no further details were provided about the nature of the images. Notably, WorldFish researchers have worked in Bangladesh to develop life-size, colored photographs of 9 commonly eaten fish species, each with 2 to 3 photographs of varying portion sizes.[100] Importantly, this photographic PSEA appropriately considered locally eaten and commonly available fish species, with the opportunity for customary portions to be considered. The extent to which accuracy of recall is improved through the use of fish- and seafood-specific photographic PSEAs is unknown and likely to vary across contexts, as demonstrated by 1 study in which, using a photographic portion guide, only 46% of participants accurately represented their plated fish portion.[97]

To obtain a sound understanding of the patterns of fish and seafood consumption, factors that can impact the frequency, quantity, and type of fish and seafood consumed by individuals need to be understood. The source and method of production (eg, aquaculture or capture) as well as details about processing methods (eg, fresh, dried, smoked, canned) can provide important information on the availability and affordability of fish and seafood, as well details of nutrient value and food safety.[7,11] Collecting this information in DATs could provide valuable data for understanding the public health implications and improve the accurate assessment of the consumption of fish and seafood.

Most studies did not include details about the validity or reliability testing of the DAT used. Some reasons for this may include the limited utilization or availability of validated tools to assess dietary fish and seafood intake in LMICs, as well as insufficient reporting of the tools used. It is also possible that studies did use validated DATs but did not explicitly mention this in the study details, in which case the use of validated DATS would be underestimated in this review. Nonetheless, according to the data reported in the Global Dietary Database, since 1980, there have been almost twice as many dietary assessments in HICs (n = 742 in 64 countries) than in LMICs (n = 869 in 130 countries) relative to the number of countries in each income group.[101] The findings of this study show a similar trend, with 51 assessments performed in upper-middle–income countries, 33 in lower-middle–income countries, and 6 in low-income countries. Numerous DATs have been developed and validated for use in HICs to measure frequency, type, and quantity of fish and seafood consumed.[102–107] However, as highlighted by this review, the application and validation of such tools for use in LMICs is much less common.

Only a small proportion of the tools included in the quality assessment were graded "good," all of which were FFQs. The low scores were primarily due to the absence of validity or reliability testing, as well as a lack of details in the description of the data collection method, scoring, or statistical methods used.

Two studies notably captured seasonal variation as well as the type, frequency, and quantity of fish and seafood intake. In the first study,[48] an NSQ was administered to 276 households in an Amazonian community. This involved the interviewer reading out a list of 36 fish species from which the household representative graded the usual weekly intake of each species on a frequency scale, followed by a 7-day recall of the types of fish consumed. On the interview day, the intra-household distribution of fish intake was measured using scales to weigh fish portion sizes.

The second study[17] involved interviewing the head of the household and the person responsible for food preparation, of 76 rural households in Bangladesh. Participants were asked to recall fish intake of the household over the last 5 days across 3 different seasons. PSEAs included food models of small and large fish, a bag of small fresh fish, and cardboard models of fish of different lengths. Intra-household fish consumption was assessed in a subset of 20 households by asking the "housewife" to prepare and distribute a commonly consumed fish dish according to the portions usually consumed by each household member.[17]

Although the tools used in both studies were not validated, they highlight how usual fish and seafood consumption can be assessed by repeating short-term dietary assessment methods or combining the methods with additional covariates for the frequency of intake. Furthermore, both studies accounted for intra-household intake and traditional eating practices, like eating from a shared plate.[16] Other approaches to accurately measuring food intake in LMICs suggest providing participants with plates from which they can eat their food on the recall day[108]; however, additional research is needed to determine if using this method would modify habitual dietary practices. Finally, 1 study[109] included measures of frequency, type, and quantity of fish in the diet of breastfeeding women. The researchers used a piloted 3-day recall questionnaire to collect households' fish consumption using everyday utensils to estimate quantities, with frequency extrapolated. The type of fish was assessed by distinguishing among the 4 most consumed species in the region. The researchers considered the amount of waste from meals to obtain an accurate measure of consumption.[109]

The strengths of this review include the use of the PRISMA guidelines[30] to ensure a robust and standardized process, a comprehensive literature search using 3 electronic databases, the inclusion of a large number of eligible studies (n = 122), and the use of an existing (modified) dietary intake methodology-reporting checklist[41] for the quality assessment. Likely, not all DATs that have been used to assess fish and seafood intake in LMICs were captured in this review, because grey-literature publications were excluded. For example, often the details of national surveys such as demographic and health surveys and household income and expenditure surveys are only available in the grey literature. Such surveys often report on the consumption or acquisition of animal-source foods, possibly including aquatic foods, and so may be a source of information on additional DATs. Grey literature, however, was considered beyond the scope of this review. It is also possible that relevant DATs developed in HICs may be applicable for adaptation to LMIC contexts. Studies from HICs were excluded from this review because of the major differences in the way seafood is typically consumed in HICs. For example, based on the authors' experience, fish and seafood in HICs is typically a high-value food from a narrow range of species with common portion and preparation methods. The further exploration of validated DATs from HICs may offer further guidance for the development of tools adapted to LMIC contexts. Furthermore, other relevant articles were possibly excluded because they were published in a language other than English.

CONCLUSION

This review has highlighted the paucity of sufficient detail on the use of standard DATs to fully capture the contribution of fish and seafood to diets in LMICs. This lack of evidence should not reduce the value of quantifying fish and seafood intake in LMICs, rather, it should be seen as highlighting the increasing need to develop validated tools that are designed to capture quantity, type, and frequency of intake with consideration of cultural eating practices, preparation methods, and intra-household intake. Furthermore, the limited reporting quality of the DATs indicates the need for more detailed, transparent, and consistent descriptions of dietary assessment methodology and the rationale for DAT selection by study authors. Together, improving the reporting of currently used DATs and developing appropriate tools could deepen the understanding of the current fish and seafood consumption patterns of those at increased risk of malnutrition, including women and children. To achieve this, validated DATs previously used in different settings could be used with adjustments for regional and cultural factors and following local validity testing. Additionally, national health surveys, which often include the frequency of intake of common food groups, could be refined to categorize aquatic food products more comprehensively by separating them from other animal-source food and including greater detail, such as the type, size, source (eg, aquaculture or capture fisheries), and preparation methods (eg, fresh, dried).[79] This could allow better evaluation of the effectiveness of local, national, and international efforts that aim to increase fish and seafood consumption, which might contribute to reducing the burden and prevalence of malnutrition in LMICs.

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Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

Table S1 **Completed PRISMA checklist**

Table S2 **Search strategy**

Table S3 **Summary of study and dietary assessment tool characteristics**

Table S4 **Quality assessment checklist for dietary intake methodology**

Table S5 **Quality assessment scoring of dietary measurement tools identified in this review**

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