Special Article

Dietary assessment in minority ethnic groups: a systematic review of instruments for portion-size estimation in the United Kingdom

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Context: *Dietary assessment in minority ethnic groups is critical for surveillance programs and for implementing effective interventions. A major challenge is the accurate estimation of portion sizes for traditional foods and dishes.* ***Objective****: The aim of this systematic review was to assess records published up to 2014 describing a portion-size estimation element (PSEE) applicable to the dietary assessment of UK-residing ethnic minorities.* ***Data sources, selection, and extraction****: Electronic databases, internet sites, and theses repositories were searched, generating 5683 titles, from which 57 eligible full-text records were reviewed.* ***Data analysis****: Forty-two publications about minority ethnic groups (n = 20) or autochthonous populations (n = 22) were included. The most common PSEEs (47%) were combination tools (eg, food models and portion-size lists), followed by portion-size lists in questionnaires/guides (19%) and image-based and volumetric tools (17% each). Only 17% of PSEEs had been validated against weighed data.* ***Conclusions****: When developing ethnic-specific dietary assessment tools, it is important to consider customary portion sizes by sex and age, traditional household utensil usage, and population literacy levels. Combining multiple PSEEs may increase accuracy, but such methods require validation.*

INTRODUCTION

Dietary assessment in minority ethnic groups is critical for surveillance programs in countries with high proportions of settled and transitory groups as well as for implementing effective interventions in these populations. Multiethnic populations living in the same country may show wide variation in prevalence rates of noncommunicable diseases such as obesity and cardiovascular disease, and such variation may be associated with dietary practices more so than with genetic background.[1] The evaluation and improvement of health outcomes through health promotion interventions in these populations requires culturally appropriate dietary assessment techniques.

In the United Kingdom, foreign-born residents made up 13% (4.6 million) of the population in 2011, with Asian and Asian British accounting for 7.5% of all residents, followed by African, Caribbean, black, and black British, totaling 3.3%.[2] Of the ethnic minorities in

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the United Kingdom, those originating from the Indian subcontinent (India, Pakistan, and Bangladesh) have among the highest rates of cardiovascular and other noncommunicable diseases.[1] Investigating the experience of disease and dietary exposures in these groups may provide etiological clues.[3]

Ethnic minority groups in countries such as the United Kingdom and the United States are immigrant groups that have settled over time, with successive generations becoming integrated into the host society. As a consequence, dietary acculturation is observed,[4] affecting dietary patterns.[5] Assessing individual diets in these groups is difficult because any tool must capture the complexity of the diet, which may be a combination of ethnic foods and those commonly consumed by the autochthonous (native) population. A further complexity is that the assessment of cultures in which food is consumed directly from a shared dish and with the hands (eg, Arab countries and some African countries)[6] may require resource-intensive techniques such as direct observation. Another well-recognized challenge in dietary assessment is the accurate estimation of portion sizes.[7] Traditional dietary assessment methods (eg, 24-hour recalls, food frequency questionnaires [FFQs], and unweighed food records) are subject to random error when estimating portion size.[8] Type of food eaten, sex and age of respondent, and the nature of the dietary assessment instrument used may also affect the validity of the data collected, especially if there is a need to recall amounts from memory.[9–11] Beyond generation and age factors, income, level of education, dietary laws, religion, and food beliefs are also influential.[6]

A considerable number of studies reporting on PSEE performance and comparing the use of PSEE types in nonethnic populations have been conducted., and these are presented in a separate publication.[12] Some of this work highlighted the lack of reported quality measures for PSEEs, particularly for those used across sociodemographic groups.[8] Other studies looked at strategies to improve the recall of portion size during dietary assessment by both interviewers and respondents,[13–15] including the use of categorical size estimates (ie, large, medium, and small) in quantitative FFQs or the use of portion-size estimation aids (PSEAs) like food models, household utensils, photos, or diagrams in 24-hour recalls.[16] In some cases, the performance of these instruments depended heavily on the characteristics of the food, particularly the shape and texture.[17,18] Because of the popularity of amorphous foods in many ethnic cultures, ie, foods that take the shape of the container they are in, such as rice and noodle dishes, and the presence of traditional foods, the use of adequate PSEAs and other portion estimation tools is particularly important. While dietary assessment techniques in ethnic minority groups have been examined,[6,19] the portion-size estimation component has not been specifically addressed.

The present review explores the existing PSEEs applicable to UK ethnic minority groups to cover this gap. For the purpose of this work, a PSEE was defined as a component of the dietary instrument designed to help quantify the amount of food reported as consumed, including PSEAs (eg, photos, everyday reference objects, household utensils, food models), categorical size estimates, household utensil measures, unit food amounts (eg, 1 slice, 1 egg), standard units of measurement (grams, ounces, milliliters), and any other quantifying component. Although this review focused on the main UK minority ethnic groups, many of the studies identified explored multiethnic populations across North America, Africa, and the Indian continent, for which the same PSEEs may be applicable.

METHODS

A systematic review of the literature for records published between 1910 and 2014 was conducted between March and September 2014, using standard systematic review guidelines[20,21] (see the PRISMA[22] checklist in Appendix 1 in the Supporting Information online). This review was based on a larger systematic review of portion-size instruments for dietary assessment,[12] from which the subgroup of tools tested in minority ethnic groups in the United Kingdom was extracted. The study protocol is available by contacting the authors.

Studies were selected for review using population, intervention, comparison group, outcome, and study design (PICOS) criteria (Table 1). Two groups of records were selected:

Group 1 (United Kingdom and related). Publications or other records reporting the development, application, or validation of a PSEE in a minority ethnic group in the United Kingdom (main minority groups, on the basis of census data[2]) or in minority ethnic groups living outside the United Kingdom if they were of the same or related ethnicity as the UK groups (eg, African American, American Chinese, American South Asian, and Caribbean).

Group 2 (country of origin). Records reporting the development, application or validation of a PSEE in the country of origin of UK minority ethnic groups (eg, Jamaica, Sri Lanka, Nigeria).

Studies were excluded if they reported the use of a dietary assessment instrument without a portion-size measuring element (eg, nonquantitative FFQs) or if the PSEE was not described in full or was not applicable for dietary assessment in minority ethnic groups, particularly for ethnic foods. Studies using food guide

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

Criterion	Description
Population	Minority ethnic populations, including Asian, Indian, Pakistani, Bangladeshi, Chinese, black, Caribbean, African, Arab, Polish, Irish, and Romani, living in the United Kingdom; or the same/related populations studied elsewhere (eg, USA; Europe); or the same/related populations studied in their country of origin (eg, Sri Lanka)
Intervention	Any intervention in which a PSEE was used to quantify dietary intake in minority ethnic groups; surveillance studies
Comparison	Other minority ethnic groups in the United Kingdom or elsewhere; autochthonous populations in the United Kingdom or elsewhere; government or health-professional dietary guidelines; studies with no control/comparator group
Outcomes	Population/individual dietary intake; method development; method validation; any other health- or diet-related outcome evaluated through the use of a PSEE
Study design	Any study design in which a PSEE is described; review papers with relevant references; health professional/NGO websites; government, academic, and industry reports. Excluded outcomes: editorial, commentary, and opinion pieces; review papers with no relevant references

Abbreviations: NGO, nongovernment organization; PSEE, portion-size estimation element.

pyramids were only included if they examined a sufficiently wide range of portion sizes across food groups and could assist with dietary assessment. Studies using instruments tested exclusively in minority ethnic groups not related to the main minority ethnic groups in the United Kingdom (eg, Native American Indian in the United States) were also excluded. In addition, titles with no accessible abstracts; editorials, commentaries, and opinion pieces; review papers with no relevant references; and papers in languages not covered by the research team were also excluded (ie, only papers in English, Spanish, French, Italian, Portuguese, Urdu, Punjabi, and Arab were included).

Searches were conducted across 21 medical, social, and economic databases (see Figure 1 for details). In addition, all titles from a published review on dietary assessment methods for minority ethnic group populations were also screened.[6] The title search was complemented by cross-referencing and by the authors' knowledge.

A search pathway containing keywords and combinations for the searches was designed and prepiloted (see Appendix 2 in the Supporting Information online). Searches were structured in blocks containing descriptors for PSEEs. The following block themes were used: portion size; tool; measures; assessment; quantity; dietary; electronic; foods; texture; and target population characteristics. Each block consisted of at least 3 descriptors. For instance, the block "portion" consisted of "portion OR serving OR helping"; the block "tool" consisted of "tool* OR utensil* OR appliance* OR guide* OR instrument*," and so on. In addition, for Group 1 records, keywords for the major minority ethnic groups in the United Kingdom were used, ie, "Ethnic OR Asian OR Indian OR Pakistani OR Bangladeshi OR Chinese OR Black OR Caribbean OR African OR Arab OR Polish OR Irish traveler OR Gypsy traveler." This was followed by a search of 19 different combinations of the above descriptor blocks, each containing the ethnic minority block. To reduce the number of ineligible hits in combinations producing more than 1000 hits, abstracts in which the words "portion" and "size" were not within 3 words of each other were excluded. For Group 2 records, the same search strategy was used, but the ethnic minority block was replaced by a country of origin block, ie,: "Asia* OR India* OR Pakistan* OR Bangladesh* OR China OR Chinese OR Caribbean OR Africa* OR Arab OR Poland OR Polish OR Romania* OR Ireland OR Irish OR Sri Lanka*."

Title and abstract screening and data extraction were carried out by 3 investigators (A.A., E.A.R., and C.G.). A subsample of abstracts was screened in duplicate to assess consistency between reviewers. Disagreements were discussed within the team to reach consensus, and further information from authors was sought when necessary. When the same instrument appeared to be reported in different publications, this was verified and the instrument included only once. If a paper's abstract did not provide enough information to determine whether eligibility criteria were met, that paper was taken forward to full review.

Information was extracted on the instrument description (ie, name, origin, dimension); the instrument technique (indirect or direct measuring) and whether it was based on a portion reference scheme; the outcome measured and the intended population use/setting; the efficacy of the tool; the relevance of the instrument to the population/target outcome; the instrument's validation and reliability status; the feasibility of the instrument (ie, low, medium, or high complexity); and the applicability of the instrument beyond the study population and context. Risk of bias in individual studies was examined by looking at study design, outcomes and analysis, and other strengths or limitations of the study, using adapted versions of published resources.[23,24] Analysis of risk of bias across studies was not applicable because this review is meant to inform decisions across a variety of settings.[23]

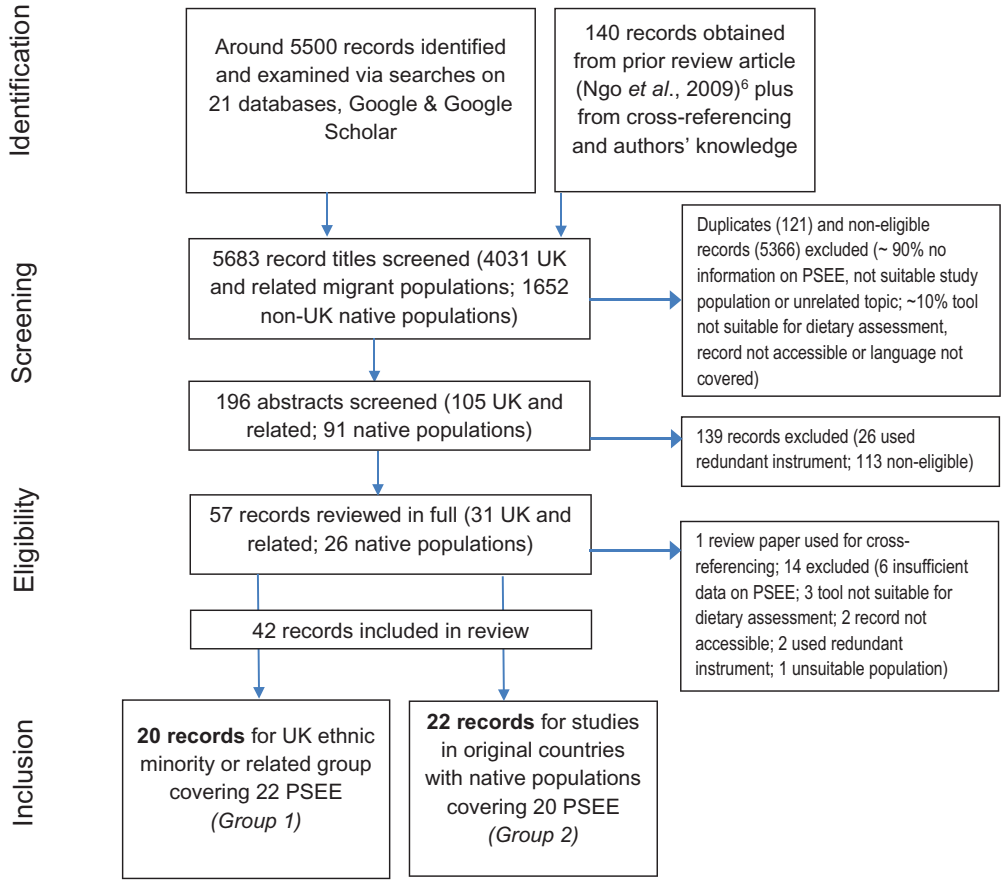

Figure 1 **Flow diagram of the literature search process.** The following databases were searched for publications reporting the use of a portion-size estimation element (PSEE) in UK minority ethnic groups and related populations (based on the PRISMA statement[22]): Database of Abstracts of Reviews of Effects, NHS Economic Evaluation Database, Health Technology Assessment, Cochrane Library, MEDLINE, Cumulative Index to Nursing and Allied Health Literature, PsycINFO, Allied and Complementary Medicine Database, Health Management Information Consortium, British Nursing Index, Health Business Elite, Embase, Oxford journals, Scopus, Web of Knowledge, Wiley Online Library, Google, Google Scholar, Electronic Theses Online Service, University of Birmingham e-Theses Respository, ChesterRep (University of Chester's online research repository), Sociological Abstracts, and EconLit.

Meta-analysis was not appropriate; rather, a narrative synthesis was conducted, and results were combined in tables and figures.

RESULTS

The search, identification, and screening process is shown in Figure 1. The searches identified 5683 record titles (approximately one-third were in the country of origin), from which 196 abstracts were screened. After removing noneligible abstracts, duplicates, and redundant instrument reporting, 57 records were retained for full review. From these, a total of 42 eligible records were retained for full analysis: 20 were aimed at a minority ethnic group in the United Kingdom or a related population outside the United Kingdom (Group 1), and 22 were related to autochthonous (native) populations in their country of origin, excluding the United Kingdom (Group 2).

Publication years ranged from 1984 to 2014, with an average of 2 publications per year. Group 1 records included 18 research articles, 1 internet site, and 1 doctoral dissertation (Table 2[2,3,10,25–50]). Group 2 records included 17 research articles, 1 government publication, 1 doctoral dissertation, and 3 conference abstracts. For 2 of the abstracts, a follow-up full-length publication could be identified and was also included[51,52] (Table 3 [11,17,18,27,35,49,51–78,79]).

Results from all studies (Groups 1 and 2)

There were 42 PSEEs identified across the 42 publications (22 PSEEs for the United Kingdom and related groups, and 20 for native populations in the country of origin). Sample sizes for all studies ranged from 11 to

Table 2 **Characteristics of 22 portion-size estimation elements (PSEEs) identified across 20 publications referring to main minority ethnic groups in the United Kingdom or in related groups elsewhere (full details provided in Tables S1–S3 in the Supporting Information online)**

Population and PSEE[a]	Description	Quality measures	Target group	Reference
African American and other ethnicities FFQ (NCI-HHHQ/Block modified; Block et al.[45])	Semiquantitative FFQ with portion list options for small, medium, or large portions based on subjective estimation vs responses from other men/women; modified to include ethnic and regional food choices	Compared against 24-h recall; reliability-tested	Specific for US immigrants and native population	Mayer-Davis et al. (1999)[25]
African American and other ethnicities Photographic FFQ	Food photographs of selected foods shown in 3 portion sizes, part of quantitative FFQ for American ethnic minority groups. Portion sizes derived from weighed food records	Compared against 24-h recall	African American, Japanese American, Latino, and white groups from Hawaii and Los Angeles	Stram et al. (2000)[26]
Afro-Caribbean British Combined PSEEs for FFQ	Combination of traditional Afro-Caribbean food models, stainless steel serving spoons, soup dishes, and unit numbers, eg, 1 egg, 1 slice	Compared against BMR	British Afro-Caribbean, free-living adults	Sharma et al. (2002)[27]
Arab Food Dome guide	Diagram with pictures and list of weights for selected foods. Based on dietary guidelines for the Arab countries. Includes suggested number of daily servings and examples of a serving	Not validated or otherwise tested	Arab people living in Arab countries or elsewhere	Musaiger (2012)[28]
Black American Food atlas	Book containing 3 different ''life-size'' portion photographs for more than 100 most frequently consumed foods in the USA.[44] Portions based on American Dietetic Association/ USDA Guidelines 2005[49]	Piloted; face-validity evaluated	Black American women taking part in a weight-loss intervention	Gans et al. (2009)[29]
Chinese American Combined PSEEs for Diet Habits Survey	Combination of portion lists, food models, and list of sample foods (including amount). Original DHS used household utensils, natural units, ounces, and qualitative descriptors,[b] some matching USDA portion sizes	DHS validated in North Americans; reliability-tested	Chinese American college students	Sun et al. (1999)[30]
Chinese American Combined PSEEs for FFQ (adapted from Willett et al.[50])	Combination of reference portion-size list plus open-ended question for number of portions per dish, along with actual size and traditional Chinese food models. Portion sizes chosen to match commonly consumed amounts (see entry under Nath and Huffman[32])	Compared against habitual diet	Chinese American women from San Francisco	Lee et al. (1994)[31]
Cuban American FFQ (Willett et al.[50])	FFQ, including reference portion-size list, plus open-ended question about portion size of nonlisted foods. Portions based on customary portions[46] or natural units (eg, 1 slice of bread), household units, and authors' experience	Compared against estimated food records	Cuban American adults residing in Miami	Nath & Huffman (2005)[32]
Indian British Combined PSEEs for 24-h recall	Combination of food models for meat pieces and chapattis (3 sizes), and household utensils. Specific questions used for shared meals, eg, those cooked to serve 10–12 people	Household utensil component previously validated and reliability-tested	Pregnant women from India living in the UK (2nd–3rd trimester)	Eaton et al. (1984)[33]
Indian British Food scales for food record	Table compression scales or hand-held extension spring scale used, along with accompanying utensils (eg, measuring jug)	Validated (based on referenced protocol)	As above	Eaton et al. (1984)[33]

(continued)

Table 2 **Continued**

Population and PSEE[a]	Description	Quality measures	Target group	Reference
Multiethnic groups Combined PSEEs for FFQ (Block modified and Block et al.[45])	Combination of portion size options, ie, small, medium, or large, based on reference portions, and food models. Reference portion set as the median gram weight of portion sizes in NHANES II, with 50% of the medium portion defined as small and 150% defined as large	Previously validated Block FFQ	Block questionnaire designed for the USA; current version modified to include Japanese and Chinese ethnic foods	Hu et al. (2009)[34]
Pakistani and white European[2] Combined PSEEs for food record[c]	Combination of household measures and volume models, package sizes, and actual weights (scales). Some of the portion sizes based on the FSA reference scheme[47]	Household utensil component previously validated and reliability-tested	Pakistani and white European migrants living in central Manchester, the UK	Vyas et al. (2003)[35]
Pakistani and white European Food models for FFQ[d]	Food models	Compared against BMR	Pakistani and white European migrants living in central Manchester, the UK	Vyas et al. (2003)[35]
Puerto Rican American Combined PSEAs for FFQ (Block modified and Block et al.[45])	Combination of open-ended question for portion size in FFQ, food models (Nasco, Fort Atkinson, WI), and household utensil volumes. For foods coming in natural units, number of units was also used. Assumed portions for models are based on USDA guidelines	Compared against 24 h recall; piloted	Puerto Rican American, may be adaptable to related groups in the UK	Tucker et al. (1998)[36]
South Asian and Italian British Food scales for food record	Weighed 7-d food records, complemented with household measures	Gold standard	Free-living, immigrant, and native women from the general population of Greater Glasgow, the UK	Anderson et al. (2005)[37]
South Asian British Food photographs (section of food atlas)	8 color photographs of traditional South Asian foods/dishes from Nelson et al. (1994)[10] and Nelson et al. (1996)[92e] on everyday crockery. For nontraditional foods, average portion sizes derived from MAFF (1994),[10] based on Gregory et al. (1990)[48]	Not validated (estimates compared against food records collected 2 y earlier)	Women from South Asian ethnic minorities living in the UK	Kassam-Khamis et al. (1999)[38]
South Asian British Food photographs for FFQ and 24-h recall	Color photographs of 10 traditional South Asian foods and dishes	Validated against weights	UK South Asian community (Indian and Pakistani mothers and children)	Husain & Khokhar (2011)[39]
South Asian British Food scales for food record	Weights compared with standard MAFF portions, Crawley (1988)[47]	Not validated	UK South Asian community only	Karim (1996)[43]

(continued)

Table 2 **Continued**

Population and PSEE[a]	Description	Quality measures	Target group	Reference
South Asian British Serving spoon and tablespoon portion-size guide	Coding and portion size manual developed for South Asian foods using serving spoons and table spoons commonly used by South Asians (average weight of a table spoon and serving spoon serving of various meat, vegetable, and rice dishes)	Not validated	South Asian population living in the UK	Sevak et al. (2004)[3]
South Asian Canadian FFQ	Ethnic FFQs with portion-size fraction list designed for South Asian and Chinese immigrants in Canada	Compared against estimated food record; reliability-tested	South Asian, Chinese, and European immigrants living in Canada	Kelemen et al. (2003)[40]
South Asian Canadian Portion-size pictorial guide	Pictorial guide with drawings of traditional South Asian foods, including measurements in inches and cups, as well as natural units. Portion sizes derived from focus groups within the South Asian community and from the literature. Based on *Beyond the Basics* guide[f]	Not validated	Specific for South Asian community	Brauer & Mian (2006)[42]
South Asian Norwegian and other ethnicities Health questionnaires	Weights and volume lists for beverages; units of bread; staple foods; and sugar. Includes a question on proportion of the meal eaten as staple foods, ie, rice, chapatti, potatoes	FFQ validated in Norwegians; questions on food habits piloted in 1 of the ethnic groups	Adult and children (15–76 y) Pakistani, Turkish, Sri Lankan, Iranian, and Vietnamese immigrants living in Oslo	Norwegian Institute of Public Health (2005)[41]

Abbreviations: BMR, basal metabolic rate; DHS, Diet Habits Survey; FFQ, food frequency questionnaire; FSA, Food Standards Agency; NCI-HHHQ, National Cancer Institute Health Habits and History Questionnaire; NHANES II, National Health and Nutrition Examination Survey II; PSEAs, portion-size estimation aids; USDA, US Department of Agriculture.
[a]Original questionnaires used in the development of specific ethnic FFQs are shown in parentheses.
[b]Examples of qualitative descriptors included "average" [amount], "typical amount," "1/2 typical amount," "lightly spread (can see the bread through it)," "scrape (can barely see the spread)"; household units included cups, tablespoons, teaspoons; bowl; natural units included number of visible eggs, number of slices, rolls, pancakes; volumes in ounces were given for a can of soda, espresso coffee drinks, and alcoholic drinks (S.L. Connor, written communication, February 2015).
[c]The authors also report the use of a previously developed African-Caribbean FFQ in the same study, which has been entered separately under Sharma et al. (2002).[27]
[d]As above.
[e]Each set of 8 photos illustrates portion sizes ranging between the 5th and 95th percentiles of distribution of portion sizes observed in the British Adult Dietary survey from1990 (Gregory et al.[48]). Dishes were photographed with the crockery most commonly associated with that dish, ie, rice, meat, vegetable, and bean curries on a plate, and dhal in a bowl.
[f]The *Beyond the Basics* guide is the main tool in Canada for teaching about the exchange system approach to managing carbohydrate intake. This pictorial guide was developed from the *Beyond the Basic* tool and was subsequently applied for educating about the metabolic syndrome (P. Brauer, written communication, May 2016).

Table 3 **Characteristics of 20 portion-size estimation elements (PSEEs) identified across 22 publications conducted in native populations in their country of origin, excluding the United Kingdom (full details provided in Table S4 in the Supporting Information online).**

Country and population	PSEE	Study design	Quality measures	Reference
Bangladesh Children aged 1–11 y with diagnosed rickets in rural and poor areas	Combined PSEEs (food scales for 24-h WFR; volume models; package information)	Observational study. Used traditional and local food and recipes, leftovers; breastfeeding	Evidence-based method; protocol followed for staged weighing; records double-checked by investigator	Ahmed (2014)[63]
Burkina Faso Rural women of low literacy participating in nutritional study	Food atlas for a 24-h recall (4 photos of portion sizes for 8 food items)	Validation against actual weight, n = 257 individuals; atlas portions based on 24-h recall	55% accuracy rate; moderate to good estimation for most foods, but under- and overestimations detected in 5 of the 8 foods; impact of education	Huybregts et al. (2008)[17]
Cameroon Adults from rural and urban sites	Combined PSEEs for EFR and for a 24-h recall, to be used in FFQ (household utensils and food models)	Development of FFQ for Cameroonians[a] (n = 123). Wide food list for traditional foods/recipes, no data on portion size	Similar utensils used in validation of final FFQ (see next entry, Mennen et al.[53]), but limited information provided on food models and utensils	Sharma et al. (1996)[77]
Cameroon Adults of African origin from rural and urban sites	Combined PSEEs for FFQ (local cooking utensils, wooden food models, cutlery)	Application of FFQ nutrient intake study in rural (n = 743) and urban (n = 1042) Cameroonians	Not validated in native Cameroonians, but related version was compared against 24-h recalls and 4-d WFRs in 96 adults of Afro-Caribbean origin living in the UK; macronutrient intake estimated within 5% of energy intake, but other nutrients overestimated	Mennen et al. (2001)[53]
India Retrospective analysis of data on children aged 1–2 y (New Delhi, 1993–1994)	Simplified portion-size assessment questionnaire for field observations (fraction of amount consumed vs amount presented)	Validation against WFR for future use in field studies; n = 128 children. Full data obtained for only 3 foods, although 5 were tested	Accounted for leftovers, spillage. Incomplete statistical analyses. Low precision and sensitivity Reliability not tested but measured previously[69]	Dhingra et al. (2007)[55]
Ireland Irish children (n = 594, aged 5–12 y), adolescents (n = 441, 13–17 y), and adults (n = 1274, 18–64 y)	Combined PSEEs for online database (digital food scales, food packaging; Nelson's food atlas[75]; government publication[73]; local food shop menus; household measures; standard units, other)	Creation of online database for food portion sizes of 545 foods on the basis of data from 3 national dietary surveys using WFR and EFR	Some components are validated tools. Sensitive tool, as based on large amount of weighed data, but portions were not differentiated by eating occasion	Lyons et al. (2013)[68]
Ireland 500 Irish preschool children (aged 1–4 y)	Combined PSEEs for 4-d WFR (food scales, food packaging; *Young Person's Food Atlas*[78]; household measures)	Creation of database of food portion sizes for preschool children. Direct (≈85%) and indirect measures (≈15%) used	Some components are validated tools. Sensitive, as based on large proportion of weighed data (75% of the weights were provided by caregivers)	Giltinan et al. (2013)[64]

(continued)

Table 3 **Continued**

Country and population	PSEE	Study design	Quality measures	Reference
Ireland 120 young residents of Ireland (aged 18–25 y), mostly of normal weight and single, 51% students	Combined and stand-alone PSEA for comparison study (food scales, measuring jug, reference objects, household measures and utensils, portion fractions, pack demarcations)	Evaluation of the precision, ease of use, and likelihood of use of a wide range of existing PSEAs for difficult-to-estimate foods, to be used optionally for particular foods	Several of the tools had not been validated (eg, hand measures). Only PSEAs relevant for Ireland were tested; qualitative data collected. Food scales and jug were the most precise, and photos the least precise	Pourshahidi et al. (2013),[66] later described in Faulkner et al. (2016)[51]
Jamaica Adults from district of Kingston	Combined PSEEs for food record and for 24-h recall to be used in FFQ (food models and household utensils)	Development of an FFQ for Jamaicans (n = 102). Wide food list for traditional foods/recipes, no information on portion size	Similar utensils used in validation of the final FFQ (see Mennen et al.[53], above). Limited information on food models and utensils	Sharma et al. (1996)[77]
Jamaica Rural- and urban-dwelling Jamaican adults	Combined PSEEs for FFQ with open-ended questions and PSEAs (local household utensils, food models, measuring cups, and measuring tape)	Comparison against 24-h recall and BMR (n = 73), and reproducibility (n = 123) of FFQ for Jamaicans of African origin	FFQ showed good reproducibility and moderate to good comparability against 12 × 24-h recalls and BMRs, but systematic error possible. High underreporting (especially by women)	Jackson et al. (2001)[57]
Nigeria Healthy adult men and women from urban settings	Combined PSEEs for 24-h recall (household measures and food models). Portion sizes based on ADA[74] and USDA[49] schemes	Cross-sectional study (n = 413) to determine portion and serving sizes of commonly consumed Nigerian foods	No validity measures or information on food models provided, but comprehensive list with average portion sizes (in weight) and serving sizes (in household measures) of traditional foods included	Sanusi & Olurin (2012)[54]
South Africa Adults from the North West province, mostly educated women	Food atlas for FFQ (photos of 3–4 portions for 37 foods, and photos of utensils)	Development and validation study vs actual weight of 20 food items (62 portions; n = 169 subjects). Based on in-depth interviews and focus groups	Overall 68% accuracy rate with even proportion of over/underestimations. Higher accuracy for solid foods (77%) than for amorphous foods (63%). Good reliability. Especially accurate for solid foods, but not practical to carry. See also MacInytre et al.[72]	Venter et al. (2000)[18]
Sri Lanka Urban children aged 10–16 y	Graduated food model for 9 commonly consumed South Asian foods in 3 sizes (based on previous research)	Validation vs actual weight of graduated food models, as assessed by 80 children. Low sensitivity (only 3 portion sizes used)	Estimated weight from models correlated well with actual weight; good method agreement. Good accuracy and precision, especially for amorphous foods. Accuracy for all foods except fish: 50%; for rice: 85%. Impact of texture	Lanerolle et al. (2013)[11]
Sri Lanka High-school children aged 10–16 y	Stand-alone and combined PSEEs (small and life-size photos, life-size line diagrams, and household spoons in 3 sizes). Portion	Validation vs actual weight (as assessed by 80 teenagers) for 4 PSEAs. Portion sizes derived from consumption studies. No test-re-test measures conducted	Accuracy rates[b]: 48% (n = 876) for small photos; 57% (n = 558) for large photos; 64% (n = 1271) for diagrams. Household utensils had lowest accuracy	Thoradeniya et al. (2012)[56]

(continued)

Table 3 **Continued**

Country and population	PSEE	Study design	Quality measures	Reference
	sizes based on government[67] and other schemes[70,71,56]		(estimated rate, 0.6%; n = 475). Combined PSEEs of all 4 aids: 68.3% (n = 3180). Diagrams produced fewest over-/underestimates but were not good for all amorphous food (photos better)	
Sri Lanka 1029 adults aged ≥30 y from rural areas	Household utensil units for 3-d EFR. Portions based on government guidelines[67]	Case–control study examining the association between intake of β-carotene from fruit and vegetables and risk of oral cancer	No information reported on the accuracy or validity of estimated portions in this population. Unable to ascertain efficacy, as no significant results obtained	Amarasinghe et al. (2013)[58]
Sri Lanka Nationally representative sample of 20 390 individuals (all ages), 4747 households	Average food and drink portion sizes customarily consumed, derived from national household consumption data	Reports monthly per capita food consumption and expenditure for 349 foods and beverages	No quality measures available. Based on consumption rather than intake data. Survey covered 98% of all households, but traditional portions may have changed over time (since 2003)	Central Bank of Sri Lanka (≈2004)[62]
Sri Lanka Sri Lankan adults from urban, rural, and estate areas, varied ethnicity Development study, n = 482 participants Nutrient intake study, n = 463 participants	Combined PSEEs for 24-h recall (household measures, single-portion food photos, Nelson's food atlas,[75] and Shahar's food atlas[76])	Development of a 90-item FFQ for Sri Lankans (Jaywardena et al.[59]); assessment of nutrient intakes in Sri Lankan adults (Jayawardena et al.[60])	FFQ prepiloted in 25 subjects. Food list expanded on the basis of popular knowledge and information from producers and local experts. Shahar's food atlas[76] is an official tool in the Malay language, covering more than 360 food items. May lack specificity, as only 4 foods included. Types of cooking oil not distinguished	Jayawardena et al. (2012)[59]; Jayawardena et al. (2014)[60]
Sri Lanka Sri Lankan adults from urban, rural, and estate areas, varied ethnicity	Combined PSEEs for FFQ (portion-size lists for 85 food items indicating average portions plus photos of 4 foods in 3 portions	Validation against 7-d WFR for previously developed FFQ (see Jayawardena et al.[59]) in 77 adults (65% women)	FFQ slightly overestimated CHO (11.5 g/d) and fat (5.7 g/d) intakes but correlated with energy, CHO, protein, fat, and fiber intakes (r = 0.17–0.47; all $P < 0.05$). Methods showed fairly good agreement but may have over-/underestimated CHO, fat, and fiber intakes	Jayawardena et al. (2013),[65] later described in Jaywardena et al. (2016)[52]

(continued)

Table 3 **Continued**

Country and population	PSEE	Study design	Quality measures	Reference
Sri Lanka Healthy elderly adults (n = 200, aged >60 y) from mostly rural areas	Combined PSEEs (household utensil units for 24-h recall, plus photos of food servings)	Comparison study for a food variety score, a dietary diversity score, and a dietary serving score vs mean adequacy ratio using 24-h recall data	The 3 dietary scores correlated with mean adequacy ratios ($r = 0.45–0.58$; all $P < 0.01$). Sensitivity and specificity analyses performed to optimize the use of the dietary diversity score and food variety score. Portion sizes improved score performance	Rathnayake et al. (2012)[61]
Sri Lanka Women (n = 100) aged 20–45 y from urban and rural areas	Household utensil units for 3-d EFR	Cross-sectional study on link between dietary CHO, physical inactivity, and central obesity in Sri Lankan housewives	No data on accuracy or validity. Able to detect associations between diet and markers of central obesity	Rathnayake et al. (2014)[79]

Abbreviations: ADA, American Dietetic Association; BMR, basal metabolic rate; CHO, carbohydrate; EFR, estimated food record; FFQ, food frequency questionnaire; PSEA, portion-size estimation aid; USDA, US Department of Agriculture; WFR, weighed food record.
[a]In the same paper, the authors also report the development of an FFQ for Jamaicans living in Jamaica (see entries for Jamaica), as well as an FFQ for Jamaican and Caribbean immigrants living in the United Kingdom (see Table 2 under Sharma et al.[27] and Vyas et al.[35]).
[b]Accuracy rate indicates the number of times a food's portion is estimated correctly, out of the total number of estimations, expressed as a percentage.

Table 4 **Characteristics of study populations for the 42 published sources reporting a portion-size estimation element (PSEEs) relevant for ethnic minorities in the United Kingdom**

Study population	No. (%) of the 42 PSEEs reported
General population (ie, free-living healthy adults)[a]	34 (81)
Based on national survey sample[b]	11 (26)
Women only	9 (21)
Children aged <19 y	5 (12)
College and secondary school students	3 (7)
Pregnant women only	2 (5)
Internet-based population	2 (5)
Participants of weight-loss program	1 (2)
UK immigrant population	10 (24)
US immigrant population	7 (17)
Other immigrant population (Canadian, Norwegian, Arab)	6 (14)
Native country population	20 (48)

[a]Excludes college/secondary school students, participants in weight-loss interventions, users of internet-based tools, and national survey sample.
[b]Includes the US second National Health and Nutrition Examination Survey (NHANES II)[45]; the US Hispanic Health and Nutrition Examination Survey (HHANES)[80]; the Dietary and Nutritional Survey of British Adults[48]; the Irish National Pre-School Nutrition Survey,[64] the Irish National Children's Food Survey, the Irish National Teens' Food Survey, and the Irish National Adult Nutrition Survey (2008–2010)[68]; and the Sri Lankan Consumer Finances and Socio-Economic Survey.[62]

20 390. Table 4 [45,48,62,64,68,80] summarizes the characteristics of the study populations across all studies. Thirty-four PSEEs (81%) were used in dietary assessment of the general population (mostly free-living adults in observational studies), 9 were used in women only (2 of which were used in pregnant women exclusively), 3 were used in secondary school or university students, and 1 was used in participants in a weight-loss trial. Eleven PSEEs (26%) were based on national survey samples. Nearly one-quarter of all PSEEs were tested in UK minority ethnic groups, while 17% were applied to US groups. Forty-eight percent of PSEEs were tested in native populations in their country of origin, excluding the United Kingdom.

Figure 2 gives information on types of PSEEs and the dietary assessment instruments in which PSEEs were applied. The most common type of PSEE (47%) was a combination tool, ie, a tool that used more than one PSEE within the same dietary assessment instrument (eg, food atlases and household utensil measures as part of the same FFQ), followed by portion-size lists (in full units or fractions) and categorical size estimates (ie, small, medium, large) from questionnaires and guides. Image-based tools and volumetric tools followed in equal prevalence (Figure 2A). The most common dietary instruments were FFQs (36%), followed by 24-hour recalls, food records, and other instruments, including databases and other questionnaires. Only one

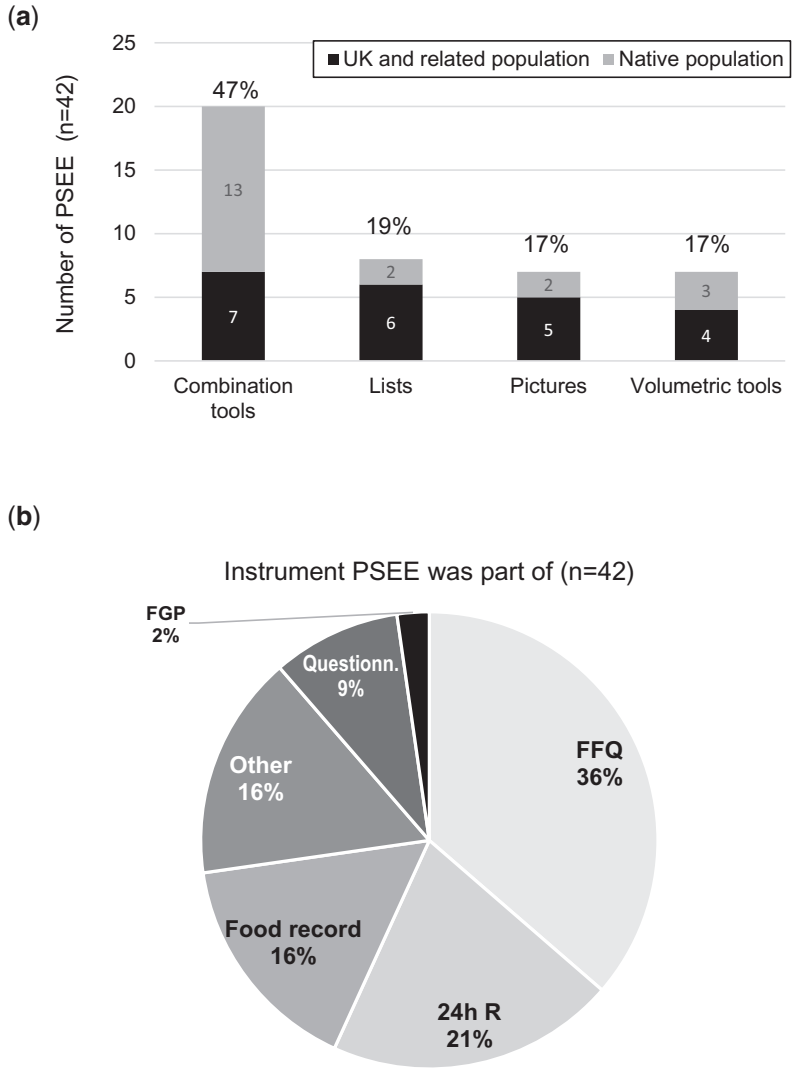

Figure 2 **Distribution of the 42 portion-size estimation elements (PSEEs) identified in this review.** (**A**) Distribution by type of PSEE. "Lists" include lists of weights or volumes, such as those in household utensil measures or units; categorical size estimates, such as small, medium, or large; fractions of a reference portion (eg, "1/2 typical amount"); and text-based package information. "Pictures" include stand-alone photos, food atlases, diagrams, and drawing/picture guides. "Volumetric tools" include household utensils, food models, food replicas, non-food reference objects (eg, deck of cards), hands, packaging demarcations, measuring tapes, measuring jugs, and food scales. "Combination tools" are tools consisting of more than one PSEE applied within the same dietary assessment instrument. (**B**) Distribution by type of dietary assessment instrument into which the PSEE was integrated. "Food record" includes both weighed and estimated records. "Other" includes databases and no specific instrument. *Abbreviations*: 24h R, 24-hour recall; FFQ, food frequency questionnaires; FGP, food guide pyramids; Non-FFQ, questionnaires other than FFQs.

eligible PSEE as part of a food guide pyramid was identified[28] (Figure 2B). Dietary assessment was the most commonly reported main purpose for which the PSEE was used, followed by development and validation or comparison studies. About 40% of PSEEs were linked to published portion-size reference schemes, including US survey data-derived schemes,[45,46] the British Adult Dietary Survey,[48] the UK Food Standards Agency portion sizes,[73] and national dietary guidelines[49,67] (Tables 2 and 3, Tables S1–S4 in the Supporting Information online).

Figure 3 gives information on study populations. The predominant population (around 50% of PSEEs) was the South Asian community, including both the immigrant and the native populations, followed by African, non-UK white European, Afro-Caribbean, Chinese, Cuban/Puerto Rican, mixed ethnicity, and Arab populations (Figure 3A). Of the South Asian populations, the most common was Sri Lankan and the least common Bangladeshi, but proportions differed depending on whether participants were immigrants or

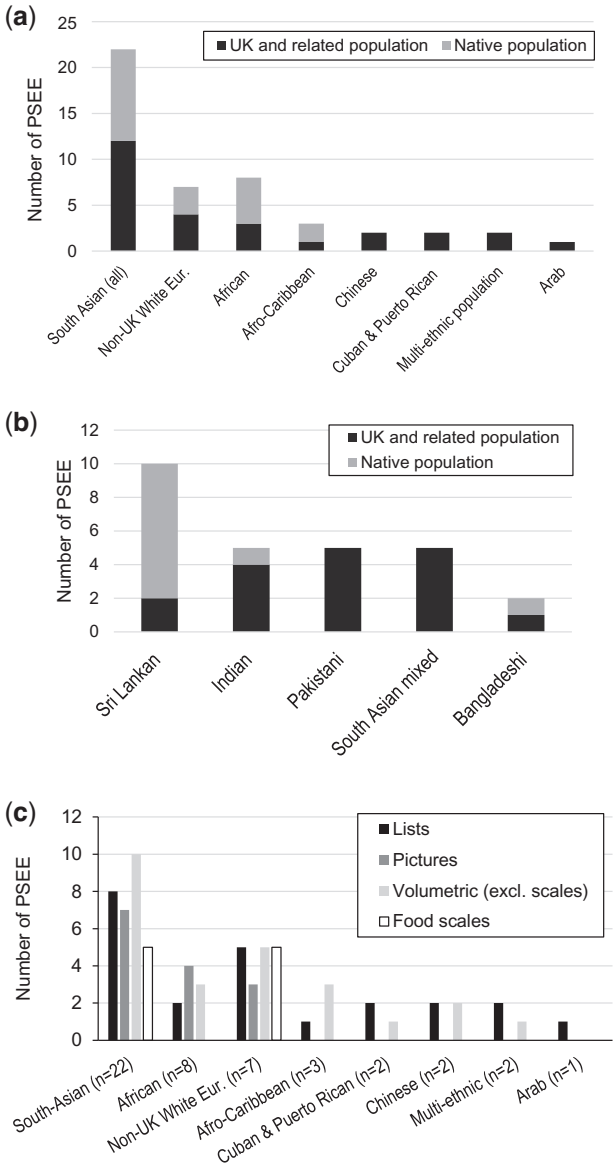

Figure 3 **Portion-size estimation elements (PSEE) by study population across the 42 publications analyzed in this review.** (**A**) Population distribution across all studies. (**B**) Population distribution across studies with South Asians. (**C**) Distribution of PSEE types by study population. "Non-UK white Eur." includes Irish, Italian, and other European populations. "Multiethnic" includes white American, Hispanic, Iranian, Japanese, Turkish, Vietnamese, and Chinese populations. The total exceeds 42 because some tools were used in various populations simultaneously. The PSEEs included in lists, pictures, and volumetric tools are as shown in Figure 2. *Abbreviation*: Eur., European; excl., excluding.

native residents (Figure 3B). Studies of South Asians employed the widest range of PSEEs (from portion-size lists to food scales), while studies of non-UK white European immigrants employed a similar range of PSEEs. A narrower range of PSEEs was used in other groups (Figure 3C).

Figure 4 and Table 5[3,11,17,18,25–43,51–59,61–66,68,77,79] summarize information on PSEE quality measures. For most of the tools, there was no absolute (comparison vs weights) or relative (comparison vs weighed food records) validity data reported, but about two-thirds of the tools were based on field observations, interviews, or previous research. For 18 PSEEs, a component had been previously validated or the PSEE was a food scale (gold standard), most commonly in UK and related samples, but 18 PSEEs had no quality data reported (Figure 4A). In total, 20 PSEEs had been validated (mostly in native populations) or calibrated against other estimating tools in comparison studies (Figure 4B). Within these 20 PSEEs, those involving PSEE-based questionnaires were the most common.[25–27,31,32,34–36,40,41] Only a few PSEEs had been validated or compared on their own, as opposed to being validated as part of a full dietary assessment instrument. These included household utensils,[33,51,66] previously validated by Edington et al.,[81] and food atlas photos,[38] previously validated by Nelson et al.,[10] but the validation had been done in native (rather than ethnic minority) populations. This also applied to other PSEEs, such as those used in the Oslo Immigrant Health Study questionnaire[41] and the dietary habits survey used by Sun et al.[30] (details in Tables S2 and S4 of the Supporting Information online, including original and follow-up data for 4 PSEEs[51,52,82,83]).

The efficacy of a PSEE (defined as the degree to which the PSEE was capable of producing a portion-size estimate that was close to the real weight of the food) was difficult to determine, as only 7 (17%) of the PSEEs reported comparisons against recent weighed data. For these studies, accuracy rates (ie, the percentage of correct estimations, either as a perfect match or as a very close match, vs actual weight, relative to the total number of estimations) were frequently but not always high (>60%). However, the limited range of foods and the small sample size of participants in some of these studies may limit their application.[11,38,55]

A UK study using food photos for 10 traditional South Asian dishes reported accurate estimates in 80% of the comparisons (defined as being between −6% and 17% of the correct weight) but used a sample of only 36 women.[39] A larger study with a food atlas tested in 169 South Africans reported 70% of 2959 estimations to be within 10% of the actual weight, but the degree of accuracy depended on the physical form of the food.[18] Similar results were reported for stand-alone photos, drawings,[84] and food models[11] tested in Sri Lankan children (n = 80), but only 55% correct estimations (based on correct photo chosen) of 1028 comparisons were reported for a food atlas tested in Burkina Faso (n = 257).[17] In Sri Lanka, an FFQ that included a set of

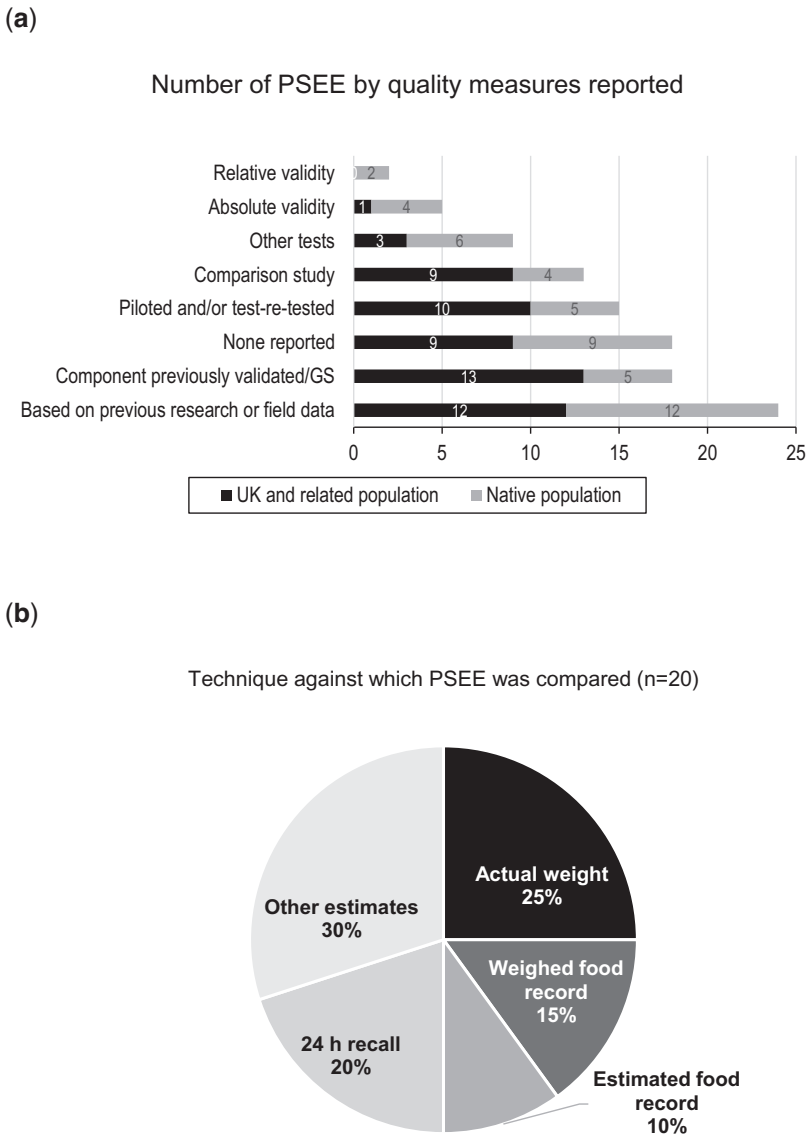

Figure 4 **Quality measures reported across the 42 studies examined in this review.** (**A**) Number of portion-size estimation elements (PSEEs) for which quality measures, no measures, related tests (eg, test of agreement), and development information (eg, component previously validated or tool based on previous research) were reported. (**B**) Proportion of techniques against which PSEEs were compared in studies reporting absolute or relative validity and in comparison studies (n = 20). *Abbreviation*: GS, gold standard.

12 food photos showed only moderate correlation and agreement with 7-day weighed food records, depending on the nutrient,[52,65] but only 3 portion sizes and 4 foods were included. In India, the Pearson correlation coefficients between estimated and weighed portion sizes for 5 foods in preschool children using a questionnaire with portion fractions[55] were on average 0.88, but such correlation cannot guarantee agreement between the 2 methods. Moreover, the foods in that study were hardly consumed, and the PSEE had a limited range of options available (for further details, see Tables S2 and S4 in the Supporting Information online).corrections up to here are fine.

Pictorial guides, FFQ lists, package information, and some image-based PSEEs were the least complex tools, owing to reduced respondent burden and ease of administering; in addition, the data obtained could be processed automatically. However, they frequently involved complex development stages and trained staff. On the other hand, household utensils, scales, and some food models were cost-effective but less portable (as were some food atlases). The need for interpreters or translation of documentation into native languages increased the complexity further.

In general, studies that used FFQs had reasonable sample sizes and a wide range of ethnic

Table 5 **Quality measures for the 42 portion-size estimation elements (PSEEs) identified in this review** (for full description of PSEEs and country of application, see Tables 2 and 3).

Reference	PSEE	Gold standard or previously validated component	Absolute validity (vs actual weight)[a]	Relative validity (vs WFR)[b]	Comparison study and reference method[c]	Piloted/test-retest	Other tests[d]	No measures reported	Based on primary data or previous research
Ahmed (2014)[63]	Combined PSEEs	NR	NR	NR	NR	NR	NR	✓	✓ (previous research)
Amarasinghe et al. (2013)[58]	HHU	NR	NR	NR	NR	NR	NR	✓	NR
Anderson et al. (2005)[37]	Scales	✓	NR	NR	NR	NR	NR	✓	NR
Brauer & Mian (2006)[42]	Picture guide	NR	NR	NR	NR	NR	NR	✓	✓ (focus groups and literature reviews)
Central Bank of Sri Lanka (2004)[62]	Average portion list	NR	NR	NR	NR	NR	NR	✓	✓ (data on consumption)
Dhingra et al. (2007)[55]	Portion-size fraction list	NR	NR	✓	NR	NR	NR	NR	NR
Eaton et al. (1984)[33]	Combined PSEEs	✓	NR	NR	NR	NR	NR	✓	NR
Eaton et al. (1984)[33]	Scales	✓	NR	NR	NR	NR	NR	✓	NR
Gans et al. (2009)[29]	Food atlas	NR	NR	NR	NR	✓	✓	NR	NR
Giltinan et al. (2013)[64]	Combined PSEEs	✓	NR	NR	NR	NR	NR	✓	✓ (food weights: 78% from care-givers; 7% from manufacturers)
Hu et al. (2009)[34]	Combined PSEEs	✓	NR	NR	NR	NR	NR	✓	✓ (focus groups and 24-h recalls)
Husain & Khokhar (2011)[39]	Food photos	NR	✓	NR	NR	NR	NR	NR	✓ (pilot data and literature)
Huybregts et al. (2008)[17]	Food atlas	NR	✓	NR	NR	✓	NR	NR	NR
Jackson et al. (2001)[57]	Combined PSEEs	NR	NR	NR	✓ (24-h recalls and BMR)	✓	NR	NR	✓ (weighed recipe data)
Jayawardena et al. (2012)[59]	Combined PSEEs	✓	NR	NR	NR	NR	NR	✓	NR
Jayawardena et al. (2013),[52] (2016)[65]	Combined PSEEs	NR	NR	✓	NR	✓	✓	NR	✓ (producers, local nutrition experts; participants)
Karim (1996)[43]	Food scales	✓	NR	NR	NR	NR	NR	✓	NR
Kassam-Khamis et al. (1999)[38]	Food atlas (section)	✓	NR	NR	✓ (FR)[e]	✓	NR	NR	NR
Kelemen et al. (2003)[40]	Portion-size options list	NR	NR	NR	✓ (EFR)	✓	NR	NR	✓ (4-d food records and 24-h recalls; data for oils)

(continued)

Table 5 **Continued**

Reference	PSEE	Gold standard or previously validated component	Absolute validity (vs actual weight)[a]	Relative validity (vs WFR)[b]	Comparison study and reference method[c]	Piloted/test-retest	Other tests[d]	No measures reported	Based on primary data or previous research
Lanerolle et al. (2013)[11]	Graduated food model	NR	✓	NR	NR	NR	✓	NR	✓ (previous research)
Lee et al. (1994)[31]	Combined PSEEs	NR	NR	NR	✓ (habitual diet)	NR	✓	NR	✓ (interviews and observations)
Lyons et al. (2013)[68]	Combined PSEEs	✓	NR	NR	NR	NR	✓	NR	✓ (food weights or manufacturer's data used in 46%–86% foods)
Mayer-Davis et al. (1999)[25]	Portion-size options list	✓	NR	NR	✓ (24-h recalls)	✓	NR	NR	✓ (expert advice, field data)
Mennen et al. (2001)[53]	Combined PSEEs	✓	NR	NR	NR	✓	NR	NR	✓ (weighed recipe data)
Musaiger (2012)[28]	FGP daily servings	NR	NR	NR	NR	NR	NR	✓	NR
Nath & Huffman (2005)[32]	Reference portion list	✓	NR	NR	✓ (EFR)	NR	✓	NR	NR
Norwegian Institute of Public Health (2005)[41]	Portion-size options list	✓	NR	NR	NR	✓	NR	NR	✓ (published research)
Pourshahidi et al. (2013)[66]; Faulkner et al.[51]	Combined PSEEs	✓	NR	NR	✓ (PSEA)	NR	✓	NR	NR
Rathnayake et al. (2012)[61]	Combined PSEEs	NR	NR	NR	✓ (MAR)	NR	✓	NR	NR
Rathnayake et al. (2014)[79]	HHU	NR	NR	NR	NR	NR	NR	✓	NR
Sanusi & Olurin (2012)[54]	Combined PSEEs	NR	NR	NR	NR	NR	NR	✓	NR
Sevak et al. (2004)[3]	HHU measuring guide	NR	NR	NR	NR	NR	NR	✓	✓ (weighed recipe data)
Sharma et al. (2002)[27]	Combined PSEEs	NR	NR	NR	✓ (BMR)	✓	NR	NR	✓ (2-d food records)
Sharma et al. (1996)[77]	Combined PSEEs, Cameroon	NR	NR	NR	NR	NR	NR	✓	✓ (weighed recipe data)
Sharma et al. (1996)[77]	Combined PSEEs, Jamaica	NR	NR	NR	NR	NR	NR	✓	✓ (UK recipe data)

(continued)

Table 5 **Continued**

Reference	PSEE	Gold standard or previously validated component	Absolute validity (vs actual weight)[a]	Relative validity (vs WFR)[b]	Comparison study and reference method[c]	Piloted/test-retest	Other tests[d]	No measures reported	Based on primary data or previous research
Stram et al. (2000)[26]	Food photos	✓	NR	NR	✓ (24–h recalls)	✓	NR	NR	✓ (3-d weighed records)
Sun et al. (1999)[30]	Combined PSEEs	✓	NR	NR	NR	✓	NR	NR	✓ (expert advice and previous research)
Thoradeniya et al. (2012)[56]	Stand-alone and combined PSEEs	NR	✓	NR	✓ (PSEA)	NR	NR	NR	✓ (previous research and data on consumption)
Tucker et al. (1998)[36]	Combined PSEEs	✓	NR	NR	✓ (24-h recalls)	✓	NR	NR	NR
Venter et al. (2000)[18]	Food atlas, including HHU photos	NR	✓	NR	NR	✓	✓	NR	✓ (interviews and focus groups)
Vyas et al. (2003)[35]	Food models	NR	NR	NR	✓ (BMR)	✓	NR	NR	✓ (focus groups; recipe data)
Vyas et al. (2003)[35]	Combined PSEEs	✓	NR	NR	NR	NR	NR	✓	NR

Abbreviations and symbol: ✓, element reported; BMR, basal metabolic rate (Schofield equations); EFR, estimated food record; FFQ, food frequency questionnaire; FGP, food group pyramid; HHU, household utensils; MAR, mean adequacy ratio; NR, not reported; WFR, weighed food record.
[a]*Absolute validity* refers to a comparison against actual weight (eg, when measured by investigators).
[b]*Relative validity* refers to a comparison against weighed food records (by participant).
[c]*Comparison studies* are those in which estimations obtained with the PSEEs were compared with estimations obtained by other methods (eg, 24-h recalls, estimated food records, and energy expenditure equations).
[d]*Other tests* include tests of agreement, sensitivity analyses, face validity, precision tests, and qualitative questionnaires.
[e]Weighed food records collected 2 years earlier.

minority–specific primary data (eg, focus groups, interviews, visits to supermarkets) and employed methods of low burden to respondents; however, the PSEEs tended to be compared against other estimating methods rather than against weighed data.[25–27,31] Studies involving specific population groups, eg, immigrant pregnant women or small samples of native populations, used more labor-intensive, sensitive methodology, mostly food scales for weighed food records, which are considered the gold standard.[33,37,52]

Several limitations were identified across most studies (Tables 2 and 3; Tables S3 and S4 in the Supporting Information online). Beyond the lack of absolute or relative measures of validity, reliability, or feasibility of some PSEEs[28,29,42,43,54,58,62,63,77,79] or the only partial validation of other PSEEs,[33,41,53,59,66,68,83] other limitations included the following: low sensitivity of the tool due to a small number of portion options or photos[11,17,25,26,29,32,40,43,52,55,65]; grouping of mixed dishes and omission of food items in questionnaires[27,35,42]; lack of breadth[28]; requirement for high level of staff training or involvement[33,37,64,68]; requirement for participants to be literate or skilled in operating equipment[33,37] or in performing numerical calculations[30]; requirement for participants to possess specific technology[29]; long time elapsed between dietary assessment with the new PSEE and the comparison method (which effectively means the 2 methods were comparing different things), or long time elapsed between test and re-test evaluations[26,38,40]; and testing of PSEE in only one gender or age group.[17,25,30–32,36–38,55,56,61,63,64,83,79] Other issues were validation conducted in nonminority ethnic group populations[30,41]; low retention rates[41,43]; study not powered to detect ethnic subgroup differences[29] or validity/reliability[38,55]; and systematic measurement error.[31] In fact, all comparison studies suffered from this last type of error by not including a measure of actual weight. Language barriers were not an issue because, in most studies, interpreters or PSEE versions in native languages were available.

Group 1 publications

There were 20 eligible studies in UK immigrants or related populations describing 22 different PSEEs (Table 2). Table S1 in the Supporting Information online provides further details, including the following: PSEE dimension; units of measure; technique used; link to portion-size reference scheme; purpose; outcome; and setting. The distribution of tool types was similar to that for the entire sample of studies, but with a lower proportion of combination tools and a higher proportion of 1- and 2-dimensional tools (Figure 2A). Moreover, as for the entire group of studies (Figure 2B), FFQs were the most common dietary assessment instrument in which PSEEs were used, and dietary assessment as part of observational studies or interventions was the most commonly reported main purpose for which the PSEE was applied. The predominant study population was still the South Asian community (55% of PSEE), followed by non-UK white Europeans and other groups (18%) (Figure 3A and B). Instruments commonly used for the South Asian community included food scales, photos, and drawings,[38,42] a household utensil guide,[3] portion-size lists as part of an FFQ,[38,43] and other questionnaires.[41] In Indian and Pakistani groups, food models, scales, household utensils,[33] and combined PSEEs[35] were used (Figure 3C).

Only one PSEE (5%) in Group 1 had been strictly validated against actual weights, and only 9 (45%) had been used in comparison studies (Figure 4A, Table 5). On the other hand, 50% of the PSEEs had been piloted and/or tested for reproducibility (compared with 23% in Group 2 studies). Sixty-five percent of the PSEEs either contained a food scale component, whereby researchers or participants had used food scales solely or alongside other tools to weigh food, or had been previously validated in part or in whole, though not necessarily in the same population (vs 23% in Group 2).

Food frequency questionnaires containing lists of portion sizes had notable limitations, including underestimation of macronutrient and overestimation of micronutrient intake,[40] lack of sensitivity/precision for specific nutrients, eg, protein and cholesterol[32] or fats,[40] and low precision in certain population groups.[25] These FFQs typically contained stand-alone PSEEs of low sensitivity with 1 to 3 portion-size options as part of a list. On the other hand, an FFQ developed to measure fruit and vegetable intake in UK South Asian women and including a bespoke household utensil guide[3] showed good validity against biomarkers of dietary phytoestrogen intake in epidemiological studies.[85] Some food photos[29,38] showed good comparability with 24-hour recalls or food records, although in some cases the sample sizes were small and performance varied by ethnic group, sex, body mass index, and education level.[26] Food models used as stand-alone tools to assist in FFQs resulted in estimates comparable with other estimates for micronutrient intake but underestimated energy intake.[34]

Combination tools were generally useful for dietary assessment of groups, to rank individuals across levels of intakes,[31,36] or to detect changes during health promotion interventions[30] but were not sensitive enough for individual assessment. Although combined PSEEs generally compared well against 24-hour recalls, systematic error and bias were an issue, resulting in misclassification of up to 10% of individuals in some

studies.[31] In general, adding volumetric tools such as food models, everyday objects, and household utensils to semiquantitative FFQs or food records improved comparability with calibrated reference methods,[34–36,86] although effective validity could not be established. The same was found for household utensil measures combined with other tools as part of 24-hour recalls[3,86] and for food records used as reference methods[33,35,36] (details in Tables 2 and 5 and Table S2 in the Supporting Information online).

Group 2 publications

There were 22 eligible publications in native populations across a total of 9 countries, describing 20 different PSEEs (Table 3 and Table S4 in the Supporting Information online). The populations studied were African adults (from South Africa, Burkina Faso, Cameroon, Nigeria); Caribbean adults (Jamaican adults); Irish adults and children; Indian and Bangladeshi children; and Sri Lankan adults and children. Both rural and urban settings were proportionally represented. Seven of the PSEEs were tested in children only. The most common PSEEs were combination tools, most of which included household utensil measures, followed by other volumetric tools (Figure 2A).

Seven of the PSEEs were used in 24-hour recalls, while the rest were designed to develop or be used in FFQs or food records (except for 5 PSEEs that did not specify a dietary instrument). Only 4 PSEEs had been fully validated against actual weights and only 2 against weighed food records, but this represented a higher proportion than that seen for Group 1 studies (Figure 4A). A comparison study[51,66] used food scales alongside other PSEAs but did not measure accuracy. Tests of agreement, sensitivity analyses, and other tests excluding reproducibility and piloting were reported for 27% of the PSEEs (compared with 15% in Group 1), while piloting/reproducibility was reported for only 23% of the PSEEs (compared with 50% for Group 1). Similar to findings for Group 1, 55% of the PSEEs in this group were based on previous research or field data (see Table 5 for examples).

Food texture had an impact on the performance of certain tools, but there was no consistent pattern. For example, in some studies, photos and diagrams worked better than volumetric tools for shaped food, while in other studies, the opposite was found. Likewise, the food atlas for South Africans from Venter et al.[18] produced a significantly higher percentage of correct responses for solid foods (77%) than for amorphous foods (63%) ($P < 0.0001$). However, in another study that compared the use of stand-alone vs combined PSEEs in Sri Lankan children, line diagrams worked better for foods with a defined shape (eg, fruit pieces), while photos were more accurate for amorphous foods (eg, curry dishes, cooked vegetable dishes).[56] Furthermore, Lanerolle et al.[11] showed that food models in 3 portion sizes correlated highly with actual weights, and Bland-Altman limits of agreement were relatively narrow between methods, but this applied mostly to the 6 amorphous foods tested (including noodles, rice, curries, pureed vegetables, and salad), since fish, papaya, and butter pieces tended to be overestimated and show greater variability.

DISCUSSION

Errors in portion-size estimation continue to be one of the main contributors to under- and overreporting during dietary assessment, and this applies to studies of minority ethnic groups as well.[6] Using extensive systematic searches, this review has identified and categorized 42 PSEEs applied to immigrant minority ethnic groups and to native individuals in the country of origin beyond the United Kingdom. Across all studies, combination tools were the most common (47% of PSEEs), followed by 1-, 2-, and 3-dimensional tools, which were found in similar proportions. Contrary to the trend seen in developed countries,[12,87,88] there was a low prevalence of computer-assisted methods applied to minority ethnic groups, which may be related to language, educational, and financial barriers. Close to 75% of all PSEEs were designed to assist with portion estimation in FFQs, 24-hour recalls, and food records (36% of all PSEEs were used in FFQs only), which illustrates the current challenges in portion-size estimation inherent to these methods. Findings across all studies are presented below, followed by highlights from Group 1 and Group 2 studies.

Findings across all studies

The main finding from this review, beyond the wide range of tools, was the lack of strictly validated tools (ie, those compared against actual weight or weighed food records), with only 17% (7 PSEEs) reporting such measures, confirming earlier work in nonethnic groups.[8] Attempts to calibrate a PSEE by comparing it with tools that produce other estimates were more common (31%), but systematic error from such comparisons cannot be excluded (a strong correlation does not mean the methods necessarily agree). Tests of agreement were reported for only 3 PSEEs. A larger proportion of the PSEEs (45%), especially combined PSEEs, included components that had been previously validated or calibrated. However, such components had sometimes been tested in a different population[41,54] or at a time

long previous to the current application,[38,45] which would affect applicability to the group with which it was intended to be used.[19,89]

The effectiveness of PSEEs per se was difficult to ascertain, because in many cases the portion-size evaluation component had been validated within the corresponding dietary assessment instrument (eg, FFQs, 24-hour recalls). For the tools that were compared against weight information, accuracy rates were moderately high (>50%), but performance depended heavily on whether the food was of a defined shape or was amorphous.[11,18,56] Moreover, individual characteristics such as habitual choice of portion size[17] and education further influenced results.[17,18,66] In addition, several tools were tested only in children, women, elderly adults, or students, and thus their efficacy in other population groups is not yet established.

When reliability of PSEEs was tested, it tended to be moderate to high (with correlation coefficients ranging from 0.4 to 0.9), though not consistently. Beyond food scales and measuring jugs,[51] the best reproducibility was seen for food atlases,[18] a combined PSEE that included measuring tape and measuring cups,[57] and portion lists in FFQs[25] and other questionnaires.[30] Stand-alone food photos[51,66] and portion-size fraction lists[40] were less reproducible, perhaps because of the increased difficulty in conceptualizing volumes when using PSEEs that do not offer an absolute or relative measure for comparison against measuring utensils, photographic series, or volumetric tools.[10,13] Beyond the known difficulties in the perception, conceptualization, and memory stages associated with the accurate recall of amounts,[10] as well as the influence of food and subject characteristics,[17,90] the concept of a serving size may not exist in some cultures, especially those in which eating from a communal serving dish is a normal practice.[6] Tools able to assist in the estimation of communal servings are thus very relevant. Some of these instruments were identified in studies conducted in the country of origin and included food photos,[17,18,60]; line drawings,[56] household utensil measures,[54] amount of food prepared/leftovers,[55] and combinations of these.[56,57]

In an attempt to increase the accuracy of estimation, combination tools were applied to FFQs and other instruments that typically produce under or overestimates. Combining 1-, 2- and 3-dimensional components can account for variation between different types of foods and has the potential to increase the accuracy of portion-size estimation when these tools are applied across a range of foods. For these reasons, it has been recommended for individual dietary assessment.[6,13] While the potential effectiveness of combination tools was highlighted in several of the studies identified,[3,34–36,53,56,86] in most cases comparisons were made against other estimating tools, and the validity of combined PSEEs was seldom demonstrated.[56]

As previously suggested,[8,10,45] the number of portion options in questionnaire-based PSEEs, the number and size of photos in food atlases, and the type of tool (eg, 2- vs 3-dimensional) were all important factors affecting PSEE performance. For example, several of the PSEEs identified were based on the Block FFQ,[45] which incorporates 3 categorical size estimates presented as multiple-choice options to be compared against a reference "medium" portion size shown in ounces, size (eg, medium), household measures, or natural units, as derived from National Health and Nutrition Examination Survey (NHANES) II data.[36] The inclusion of the 3 portion-size options – compared with the inclusion of only the NHANES median portion size – resulted in higher correlations for energy, fat, percent calories from fat, and vitamins A and C when compared with a 24-hour food record, but the descriptions of a reference medium portion are still prone to subjective interpretation. Specifically, the use of household measures may reflect measurement convenience and approximation rather than a behavioral truth, and measures may differ between ethnic groups and the native population.[6] One way to overcome this problem is to collect data on the capacity of usual household utensils and use this information in subsequent assessments[5] to produce ethnic-specific utensil guides[3] or to conduct individual assessment, using the number of people in the household and the proportion of food taken from the total amount prepared.[6]

As for the number of photos in photographic series, the inclusion of 3 portion-size options in FFQs is likely to improve estimation relative to having no aid,[10] but this method may not be sufficiently sensitive in certain populations such as African Americans[26] and South Asians.[52] Nelson et al.[10] found that a series of 8 photos was associated with smaller errors of estimation when compared with a single photo. As a result, a series of photos was incorporated into their food atlas, although this increased the complexity of the atlas, making it impractical for large epidemiological studies. The application of food models alongside open-ended questions about portion size in FFQs may, in theory, increase sensitivity by allowing the questionnaire to add personal variability in food preferences and quantity to the age and sex components.[45] However, no studies in this review demonstrated validity in this context. The only study that attempted to calibrate food models as part of an FFQ[31] suffered from systematic error by including the models in the calibration of both the FFQ and the reference method.

User acceptability of the PSEE is important for continued application of the tool, but this was seldom

reported. Food scales and measuring jugs were the least preferred tools in a study that compared a wide range of PSEAs in Irish adults,[51] who also rated household utensils as the easiest to use and the most likely to be used in the future, even though being the least precise. It is likely that PSEEs requiring numerical calculations,[51] volume conceptualization,[10,90,91] or prolonged time due to complexity or size (eg, food atlases)[51,52] may present barriers to implementation. In such cases, more culturally appropriate tools that allow for customary serving and eating practices may need to be considered.

Highlights from Group 1 studies

A large number of PSEEs applied to immigrant populations in the United Kingdom or to related groups elsewhere tended to be part of FFQs used in epidemiological studies. For such studies, complex development stages were sometimes reported, illustrating the challenges in developing any new tool that is culturally sensitive. For example, a UK study that developed an FFQ for South Asians included exhaustive data collected on recipes and more than 200 traditional foods and dishes (Kassam-Khamis et al.[38]).

Many of the PSEEs used in related immigrant populations outside the United Kingdom were similar to those used in the United Kingdom (eg, those that included combinations of image- and list-based PSEEs), but they may need to be adapted for application in the United Kingdom, especially for portion sizes of commercial products. While the study populations may share a common country of origin, acculturation is likely, and the impact of host country food practices on the immigrant's diet may be significant. Still, some of the tools have good potential for adaptation, such as the *Beyond the Basics* pictorial guide for Canadian South Asians,[42] which, although not validated, is simple to use and has been applied in diabetes and metabolic syndrome education (P. Brauer, written communication, May 2016). Another such tool is the Oslo Immigrant Health Study questionnaire for Norwegian South Asians,[41] which includes questions on acculturation as well as a question on the proportion of staple foods to other foods included in the dish. Another potentially adaptable PSEE is the Chinese version of the Diet Habit Survey,[82] which quantifies usual amounts of spreads on bread with descriptors such as "lightly spread (can see the bread through it)" and "scrape (can barely see the spread)"[30] and allows the conversion of household utensil amounts and commercial drinks into volumetric units (S.L. Connor, written communication, February 2015). Some of these components may facilitate understanding in first-generation immigrants, even though they are subject to personal interpretation and may require numeracy skills.[41]

Highlights from Group 2 studies

There was a relatively wide range of PSEEs identified in the countries of origin that may be applicable to immigrant populations elsewhere and that provide useful insight, especially into the feasibility and cultural acceptability of the PSEE. The PSEEs used in this group typically contained low-cost, culturally appropriate components such as local household utensils or everyday reference objects. Food photos and food models were also used frequently, especially in deprived areas. Results from studies in Sri Lankan children suggested that using a combination of PSEAs that includes life-size representations of traditional foods is probably more suitable than using a single stand-alone tool in that population. Nevertheless, a wider range of food types needs to be explored with such tools, as performance depended heavily on food texture, and no consistent pattern was seen across studies (ie, some studies favored food picture–based PSEEs for foods with defined shape[18,56] and food models for amorphous food,[11] while others showed the opposite[56]). Household utensils, on the other hand, were the least precise and least accurate in at least 2 studies,[51,56] as observed in some Group 1 studies.[5,32] While simple instruments may be nonintrusive, quick to complete, and suitable for low-literacy groups or those not speaking the language of the host country, limitations in the validity and reproducibility of such tools need to be considered. Specifically, several studies[53,61,66] compared PSEEs against estimates rather than actual weights, and some studies tested a limited number of foods, portion options, and individuals or used low-precision instruments.[11,17,52,55] Thorough methodology in the collection of traditional food lists and portion sizes is also essential to obtain good reliability and validity measures, especially when variability exists between and within geographical areas.[35,77]

Finally, many Group 2 studies included information on typical serving sizes, traditional utensils, and foods commonly consumed from a shared dish, in addition to information on portion size,[17,54,72] all of which may be useful when adapting existing dietary instruments to minority ethnic group populations.

Comparison with previous work

In line with previous studies,[6,19] this review identified a large variety of methods for estimating usual portion size, particularly within FFQs (36% of all PSEEs). These PSEEs tended to be one-dimensional (eg, consisting of

lists of average portion sizes) and were used with or without visual aids.[25,34,40.] Visual aids were added with the aim of increasing specificity to capture the diets of the differing groups within each ethnicity without introducing differential bias for ranking individuals on the basis of food and nutrient intakes.[36]

Regarding the low prevalence of computer-assisted methods, the present results agree with those reported by Ngo et al.,[6] who found that 67% of 46 studies in European minority ethnic groups used noncomputerized visual aids, and 50% applied previously identified serving sizes in target ethnic groups. In the group of studies in countries of origin, household utensils and everyday objects were typically used. These can be easily bought in the community and are cheap and simple to apply, which may explain their widespread use in low-resource countries.

The lack of a consistent pattern with regard to the impact of food texture on PSEE performance also confirms previous findings,[15,17,51] suggesting that estimation accuracy may interact with other uncontrolled factors such as a participant's experience, level of attention, willingness to cooperate, or education.[17,51] A study in British adults in which photos were compared with weighed foods reported less accuracy in estimating French fries, mashed potatoes, and spaghetti than in estimating cornflakes,[92] while a study in Norwegian children[93] found that mashed potatoes and cornflakes, in addition to other shaped or amorphous foods, were the most accurately estimated foods. A third UK study using photos of single-portion foods also failed to find any consistent association between the texture of 17 foods and PSEE accuracy.[15] However, the methodologies in some of these studies differed from each other (eg, estimation of food 5 minutes after consumption vs the following day or later), and none of the studies focused on minority ethnic foods.

Regarding the accuracy of nutrient estimation, a previous review[19] suggested that mean intakes estimated from FFQs may be higher than intakes estimated using reference methods (eg, 24-hour recalls), but this depended on the reference method and, in particular, the PSEE used.[19] In the present review, intakes of nutrients and energy also differed from those estimated using reference methods, and some correlated well with the reference method, but only in certain ethnic subgroups.[25,34] Even in instruments adapted to be ethnic specific, misreporting was an issue[35] and was associated with higher rates of overweight, especially in women.[53] Overall, since many of the studies examining nutrient intakes used estimates as comparators, it is difficult to ascertain PSEE efficacy. Thus, the validity, sensitivity, and specificity of PSEEs still need to be considered, even if the PSEE was previously tested in an ethnic minority population.

The South Asian community was a commonly studied target group (examined in 20% of studies) in a previous review of European immigrants,[6] showing the greatest variety in terms of dietary assessment methods. Acculturation was measured in 87% of the studies, while only 2 (9%) of the studies in the present review reported measuring this aspect.[31,41] One study that measured acculturation, the Oslo Immigrant Health Study,[41] includes an index of dietary integration alongside questions on availability, cost, and quality of foods[94] and can thus be used as a cross-disciplinary tool to investigate how demographic and sociocultural factors may modify food habits in minority ethnic groups.

Strengths and limitations of this review

Previous reviews have highlighted the importance of accurate estimation of portion size for both population and individual assessment in ethnic minority groups,[6,19,89] yet the PSEE itself was not specifically addressed. The present review focused on UK ethnic minorities and related populations, and so the results may not be applicable to other groups such as Native Indian Americans and European minority ethnic groups, for which data are not yet available (eg, Polish). However, considerations related to the versatility, validity, and specificity of the instrument and to method development are likely to apply. A meta-analysis of the relative effectiveness of each instrument was not performed because measures of error were not reported in all the studies, but this would be worth exploring in the future. Three Irish studies were included because the Irish were identified as a UK minority group from census data. These studies, however, sometimes used UK portion reference schemes[68] and foods similar to those traditionally consumed in the United Kingdom. Therefore, information about the PSEEs from the Irish studies may not be relevant to certain ethnic minorities. In addition, more than 75% of the PSEEs described here were applied across various age and sex population groups, but some were tested only in women, children, or first- or second-generation migrants, thus preventing conclusions about their general application. The use of a controlled environment also may have influenced the results,[11,15,39,51] as participants might have been more aware of their portion size than in normal day-to-day situations. Finally, while portion size has been recognized as a growing contributor to variation in intakes in recent years, frequency of consumption continues to be the major cause of variation.[95,96] It is therefore important to ensure that errors associated with portion-size estimation do not mask true variability in portion size.

Table 6 **Areas to consider when assessing portion size in minority ethnic groups**

Area	Considerations
Validity	Whenever possible, choose a validated portion estimation instrument that has been compared against weighed data and tested for reliability in the population of interest. For new and existing tools, consider collecting information about customary portions by sex and age as well as by traditional household utensil measures via interviews or food records
Specificity	Consider using PSEEs that allow flexibility in estimating portions of traditional foods, including mixed recipes and ingredients/components. Examples may include bespoke tools, such as traditional food models, or a combination of instruments to be applied across a range of food types (eg, depending on food texture or shape, photos or food models may be used)
Breadth	For low-literacy groups, the ratio of staple food to vegetable/meat mixes may be a useful complementary measure obtainable with questionnaires, food models, or photos, in addition to food-specific portion size. When assessing changes in food habits in minority ethnic group populations, consider instruments that can measure food-related contextual factors and integration of the ethnic group into the country of residence
Native population data	Information on traditional foods, recipes, customary portions, and ways of serving may be found in studies conducted in the country of origin. This information may not always be representative of minority ethnic group diets (consider the generation and the degree of acculturation)
Special considerations for FFQs	Reference portion sizes need to be representative of the ethnic minority group studied and not taken from the general population because distributions may be skewed. The inclusion of FFQ options to indicate larger or smaller amounts from a reference portion, or the use of an open-ended question, may be more accurate than including a single reference portion. If open-ended questions about portion size are used, an accompanying aid such as photos or food models may increase accuracy of the tool

Abbreviations: FFQ, food frequency questionnaire; PSEEs, portion-size estimation elements.

CONCLUSION

Accurate assessment of portion sizes and intake of ethnic diets requires certain considerations about the use of PSEEs, food lists, and food composition databases.[6] This review identified 5 main areas to consider when estimating portion size in minority ethnic groups (Table 6). The PSEE needs to allow flexibility in the estimation of native, traditional recipes and to consider how food is eaten and served. Assessment may be improved by the use of combined PSEEs, especially for diets in which staple amorphous foods are common (eg, rice, couscous). However, the validity of any combined PSEE needs to be established beforehand, especially for the selective application of each component by food type, since using a combined PSEE across all foods could increase measurement error.

If household measures are used as a guide for volumes, the utensils employed for assessment need to be culturally appropriate, and the actual volume of each utensil may need to be measured. In low-literacy groups, it may be practical to investigate the ratio of staple food to vegetable/meat mixes using questionnaires, bespoke food models, or photos and to adapt the PSEE accordingly in future assessments. If a list of reference portion sizes is used, for example in an FFQ, the use of categorical size estimates or food models may improve results over using a single average portion. The reference portion sizes need to be representative of the ethnic group studied and account for sex and age differences. Studies in the country of origin provide invaluable information on ethnic recipes, foods, and serving sizes, but the foods typically consumed by related minority ethnic groups elsewhere may differ as a result of acculturation. Investigation in the host country may still be necessary, followed by validation against weighed data.

In summary, a variety of PSEEs have been reported in South Asian and other minority ethnic groups in the United Kingdom and in related groups elsewhere. Instruments suitable for use in low-literacy populations, such as household utensils, photos, and food models, are commonly used, but their efficacy has not always been demonstrated. For epidemiological studies, PSEA-assisted questionnaires save time and reduce participant burden but may have a limited number of portion-size options, require participant conceptualization skills, and involve complex developmental stages to be representative of the minority ethnic group diet. The use of computerized portion estimation tools warrants full investigation, as virtually no studies have explored these tools in minority ethnic groups, yet they may offer logistic advantages over traditional methods (eg, by having a wider reach). Validated instruments for groups with specific customary eating practices (eg, shared dishes, eating from hand) are particularly needed. Combined PSEEs show high potential for both group and individual assessment in ethnic minorities, but their validity needs to be more widely established.

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Supporting Information

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

Appendix S1 **PRISMA checklist**

Appendix S2 **Search pathway**

Table S1 **Description of 22 portion-size estimation elements (PSEE) identified across publications referring to major migrant groups in the UK or to related groups elsewhere**

Table S2 **Effectiveness, validation and generalizability of 22 portion-size estimation elements (PSEE) identified across publications referring to major migrant groups in the UK or to related groups elsewhere**

Table S3 **Quality evaluation of published sources reporting portion-size estimation elements (PSEE) applied to major migrant groups in the UK or to related groups elsewhere**

Table S4 **Details of studies conducted in original countries relevant for UK ethnic minorities (20 portion-size estimation elements)**

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