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Special Article

Dietary assessment in minority ethnic groups: A systematic review of portion size estimation instruments relevant for the UK.

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ABSTRACT

Context: Dietary assessment in minority ethnic groups is critical for surveillance programmes and for implementing effective interventions. A major challenge is the accurate estimation of portion sizes for traditional foods/dishes.

Objective: To systematically review published records up to 2014 describing a portion size estimation element (PSEE) applicable to dietary assessment of UK-residing ethnic minorities.

Data sources, selection, 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 aimed at minority ethnic groups (n=20) or autochthonous populations (n=22) were included. The most common PSEE (47%) were combination tools (e.g. food models and portion size lists); followed by portion size lists in questionnaires/guides (19%); image-based and volumetric tools (17% each). Only 17% PSEE 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 PSEE may increase accuracy but such tools need validating.

Key Words: portion size tools, portion size estimation aids, dietary assessment, minority ethnic groups

INTRODUCTION

Dietary assessment in minority ethnic groups is critical for surveillance programmes in countries with high proportions of settled and transitory groups, and for implementing effective interventions in these populations. Multiethnic populations living in the same country may show wide variation in prevalence rates of non-communicable diseases such as obesity and cardio-vascular disease that may be associated with dietary practices beyond genetic background[1]. Culturally-appropriate dietary assessment techniques are important to evaluate and improve health outcomes in these populations through health promotion interventions.

In the UK, 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 at 3.3%[2]. UK ethnic minorities originating from the Indian subcontinent (India, Pakistan and Bangladesh) have amongst the highest rates of cardiovascular and other non-communicable diseases[1]. Investigating the experience of disease and dietary exposures in these groups may provide aetiological clues[3].

Ethnic minority groups in countries such as the UK and USA are immigrant groups which have settled over time and successive generations become 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 as any tool has to 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 of cultures where food is consumed directly from a shared dish and with the hands (e.g. Arab countries and some African countries)[6] where resource-intensive techniques such as direct observation may be needed. Another well-recognized challenge in dietary assessment is the accurate estimation of portion sizes[7]. Traditional dietary assessment methods (e.g. 24 h recalls, food-

frequency questionnaires (FFQs), and unweighed food records) are subject to random error caused when estimating portion size[8]. Type of food, 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 portion size estimation element (PSEE) performance and comparing PSEE types in non-ethnic populations have been conducted and these will be presented in a separate publication[12]. Some of this work highlighted the lack of reported quality measures for PSEE in particular across socio-demographic 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 (i.e. 'large', 'medium' and 'small') in quantitative FFQs or using portion size estimation aids (PSEA) like food models, household utensils, photographs or diagrams, in 24 h recalls[16]. In some cases the performance of these instruments depended heavily on the type of food, in particular shape and texture[17,18]. Because of the popularity of amorphous foods in many ethnic cultures, that is, foods that take the shape of the container they are in, such as rice and noodle dishes, plus 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 before[6,19], the portion size estimation component has not been specifically addressed. The present review focused on exploring existing portion size estimation elements (PSEE) applicable to UK ethnic minority groups to cover this gap. For the purpose of this work, **PSEE** were defined as a component of the dietary instrument designed to help quantify the amount of food reported as consumed including: PSEA (e.g. photographs, everyday reference objects, household utensils, food models); categorical size estimates; household utensil measures, unit food amounts (e.g. 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 multi-ethnic populations across North America, Africa and the Indian continent for which the same PSEEs may be applicable.

METHODS

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

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

Group 1 (UK and related): publications or other records reporting the development, application or validation of a PSEE in a minority ethnic group in the UK (main minority groups based on census data[2]); or in minority ethnic groups living outside the UK if they were of the same or related ethnicity as UK groups (e.g. 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 groups (e.g. Jamaica, Sri Lanka, Nigeria).

Exclusion criteria included: studies reporting the use of a dietary assessment instrument without a portion size measuring element (e.g. non-quantitative FFQs); or when the PSEE was not described in full; or was not applicable for dietary assessment in minority ethnic groups, in particular for ethnic food. Food guide pyramids were only included if they provided a sufficiently wide range of portion sizes across food groups and could assist during dietary assessment. Instruments tested exclusively in minority ethnic groups not related to the main

minority ethnic groups in the UK (e.g. Native American Indian in USA) were also excluded. In addition, titles with no accessible abstracts, editorials, commentary or opinion pieces, review papers with no relevant references, and papers in languages not covered by the research team were also excluded (i.e. 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 the titles from a published review on dietary assessment methods for minority ethnic group populations were also screened[6]. Title search was complemented by cross-reference and from the authors‘ knowledge.

A search pathway containing keywords and combinations for the searches was designed and pre-piloted by two of the authors (CG and EAR) (Appendix 2 in Supplementary Information). Searches were structured in blocks containing descriptors for portion size estimation elements. 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 UK were used, i.e.: 'Ethnic OR Asian OR Indian OR Pakistani OR Bangladeshi OR Chinese OR Black OR Caribbean OR African OR Arab OR Polish OR Irish traveller OR Gypsy traveller’. This was followed by searching 19 different combinations of the above descriptor blocks each containing the ethnic minority block. To reduce the number of ineligible hits in combinations producing >1000 hits, abstracts where 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 i.e.: ‘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 plus data extraction was carried out by three investigators (AA, EAR and CG). 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. Papers with abstracts for which it was unclear if they met eligibility criteria were taken forward to full review.

Information was extracted on the instrument description (i.e. name, origin, dimension); the instrument technique (indirect or direct measuring) and whether it was based on a portion reference scheme; the measured outcome and intended population use/setting; the efficacy of the tool; the relevance to the population/target outcome; validation and reliability status; feasibility of the instrument (i.e. low, medium, high complexity) and applicability beyond the study population and context. Risk of bias in individual studies was examined by looking at the study design; outcomes and analysis; plus 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 as this review is meant to inform decisions across a variety of settings[23].

Meta-analysis was not appropriate, and therefore the results were combined in tables/figures plus a narrative synthesis.

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 non-eligible 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, of which 20 were aimed at a minority ethnic group in the UK, or a related population outside the UK (Group 1); and 22 were related to autochthonous (native) populations in their country of origin excluding the UK (Group 2).

Publication years ranged from 1984 to 2014 with an average of 2 publications per year. Group 1 records included 18 research articles, one internet site and one PhD dissertation (**Table 2**[3,10,25-51]). Group 2 records included 17 research articles, one government publication, one PhD dissertation and three conference abstracts. For two of the abstracts, a follow-up full publication could be identified and was also included[52,53] (**Table 3** [11,17,18,27,35,49,52-79]).

Results from all the studies (Groups 1 and 2)

There were 42 PSEE identified across the 42 publications (22 PSEE for UK and related groups; and 20 for native populations in the country of origin). Sample sizes for all studies ranged from 11 to 20,390. **Table 4** [45,48,63,65,69,80] summarises the characteristics of the study populations across all studies. Eighty-one percent (n=34) PSEE were applied in dietary assessment for the general population (mostly free-living adults in observational studies); nine PSEE were applied in women only of which two in pregnant women, three in secondary school or university students and one in participants in a weight loss trial. Eleven (26%) PSEE were based on national survey samples. Nearly a quarter of all PSEE were tested in UK minority ethnic groups vs. 17% in USA groups. Forty-eight percent of PSEE were tested in native populations in their country of origin, excluding the UK.

Figure 2 gives information on PSEE types and dietary assessment instruments where they were applied. The most common PSEE (47%) were combination tools i.e. tools made of more than one PSEE applied within the same dietary assessment instrument (e.g. food atlases and household utensil measures as part of the same FFQ); followed by portion size

lists (in full units or fractions) plus categorical size estimates (i.e. ‘small’, ‘medium’, ‘large’) from questionnaires and guides. Image-based tools and volumetric tools followed in equal prevalence (**Fig. 2a**). The most common dietary instruments were FFQs (36%), followed by 24h recalls, food records, other instruments including databases and other questionnaires. Only one eligible PSEE as part of a food guide pyramid was identified[28] (**Fig. 2b**). Dietary assessment was the most common reported main purpose for which the PSEE was used, followed by development and validation or comparison studies. About 40% of PSEE 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[74] and national dietary guidelines[49,68] (**Table 2 and 3** Supplementary Tables S1-S4).

Figure 3 gives information on study population**.** The predominant population (around 50% of PSEE) was the South Asian community, both as immigrants as well as native population, followed by Africans, non-UK White Europeans, Afro-Caribbeans, Chinese and Cuban/Puerto Rican and mixed ethnicity groups plus Arabs (**Fig. 3a**). Within the South-Asian populations the most common were Sri Lankans and the least common Bangladeshi, but proportions differed depending on whether participants were immigrants or native residents (**Fig. 3b**). Studies with South-Asians employed the widest range of PSEE (from portion size lists through to food scales), while studies with non-UK White European immigrants employed a similar range of utensils. A narrower range of PSEE were applied in other groups (**Fig. 3c**).

Figure 4 and **Table 5** [3,11,17,18,25-43,52-60,62-67,69,78] summarise 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 were based on field observations, interviews or previous research. For 18 PSEE a component had been previously validated, or the PSEE were food scales, commonly in UK and related samples, but 18 PSEE had no quality data reported (**Fig. 4a**). In total 20 PSEE had been

validated (native populations mostly) or calibrated against other estimating tools in comparison studies (**Fig. 4b).** Within these, studies involving PSEE-based questionnaires were the most common[25-27,31,32,34-36,40,41]. Only a few PSEE had been validated or compared on their own as opposed to as part of a full dietary assessment instrument. These included household utensils[33,52,67] previously validated by Edington *et al*.[81]; and food atlas photographs[38], previously validated by Nelson *et al*.[10] but the validation had been in the native (rather than ethnic minority) population. This also applied to other PSEE such as those found in the Oslo Immigrant Health Study questionnaire[41] and the Diet Habits Survey[30] PSEE (details in supplementary **Tables S2 and S4** including original and follow-up data for four PSEE[52,53,82,83]).

PSEE efficacy (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 seven (17%) of the PSEE reported comparison against recent weighed data. For these studies accuracy rates (that is, 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 small participant samples in some of these studies may limit their application[11,38,56]. A UK study using food photographs 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 employed a sample of 36 women only[39]. A larger study with a food atlas tested in 169 South-Africans, reported 70% out of 2959 estimations being within 10% of actual weight but this depended on food physical form[18]. Similar results were reported for stand-alone photographs, drawings[84] and food models[11] in Sri Lankan children (n=80), but only 55% correct estimations (based on correct photograph chosen) out of 1028 comparisons were reported for a food atlas in Burkina Faso (n=257)[17]. Also in Sri Lanka an FFQ including a set of 12 food photographs showed only moderate correlation and agreement vs. 7 day weighed food records depending on the nutrient[53,66], but only three portion sizes and 4 foods were

included. In India, Pearson's correlation coefficients between estimated and weighed portion sizes for 5 foods in pre-school children using a questionnaire with portion fractions[56] were on average 0.88, however such correlation cannot guarantee agreement between the two methods. Also the foods in this study were hardly consumed and the PSEE had a limited range of options available (for further details see Supplementary Tables S2 and S4).

FFQ lists, guides, package information and some image-based PSEEs were the least complex tools, due to reduced respondent burden and ease to administer plus the data may be automatically processed. 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 of reduced portability (as were some food atlases). Complexity increased further by the use of interpreters and the need for translated documentation in native languages.

In general, studies involving FFQs employed reasonable sample sizes and a wide range of ethnic minority-specific primary data (e.g. focus groups, interviews, visits to supermarkets) and low-respondent burden methods however the PSEEs tended to be compared to other estimating methods rather than against weighed data[25-27,31]. Studies involving specific population groups, e.g. immigrant pregnant women or small native population samples, used more labour intensive, but sensitive methodology, mostly food scales for weighed food records which are considered the gold standard[33,37,53].

Across studies, several limitations were identified (**Table 2, Table 3** Supplementary tables S3 and S4). Beyond the lack of absolute or relative validity, reliability or feasibility measures for the PSEE[28,29,42,43,55,59,63,64,78,85]; or PSEE only partially validated[33,41,54,60,67,69,83], other limitations included: low tool sensitivity including small number of portion options or photos[11,17,25,26,29,32,40,43,53,56,66]; grouping of mixed dishes and omission of food items in questionnaires[27,35,42]; lack of breadth[28]; requiring high level of staff training or

involvement[33,37,65,69]; requiring participant to be literate or skilled in operating equipment[33,37] or in performing numerical calculations[30]; or to be in possession of specific technology[29]; long-time elapsed between dietary assessment with the new PSEE and the comparison method (which effectively means the two methods are comparing different things), or in between test and re-test evaluations[26,38,40]; and PSEE tested only in one gender or age group[17,25,30-32,36-38,56,57,62,64,65,83,85]. Other issues were validation conducted in non-minority ethnic group populations[30,41]; low retention rates[41,43] and study not powered to detect ethnic sub-group differences[29] or validity/reliability[38,56]; and systematic measurement error[31]. Strictly, all comparison studies suffered from this type of error by not including a measure of actual weight. Language barriers were not an issue as in most studies versions in native languages or interpreters were available.

Group 1 papers

There were 20 eligible publications in UK immigrants or related populations describing 22 different PSEEs **(Table 2)**. Supplementary Table S1 provides further details including PSEE dimension; units of measure; technique used; link to portion size reference scheme; purpose; outcome; and setting. The distribution of tool types was similar as for the general sample of studies but with a lower proportion of combination tools and a higher proportion of one and two-dimensional tools (**Fig. 2a**). As for the whole group of studies (**Fig. 2b**), FFQs were the most common dietary assessment instrument where PSEEs were used and dietary assessment as part of observational studies or interventions was the most common 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%) (**Fig. 3a-3b**). Instruments commonly used for the South-Asian community included food scales, photographs and drawings[38,42], a household utensil guide[3], portion size lists as part of an FFQ[38,43] and other questionnaires[41]. Indian and Pakistani groups used food models, scales, household utensils[33] and combined PSEE[35] (**Fig. 3c**).

Only one PSEE in this group (5%) had been strictly validated against actual weights and only 9 (45%) had been used in comparison studies (**Fig. 4a, Table 5**). On the other hand 50% of the PSEE had been piloted and/or tested for reproducibility (compared with 23% in Group 2 studies). Sixty-five percent contained a component that were food scales whereby researchers or participants had used the food scales solely or alongside other tools to weigh food, or the tool had been previously validated partly or wholly but not necessarily in the same population (vs. 23% in Group 2). FFQs containing lists of portion sizes suffered from limitations including underestimation of macronutrient and overestimation of micronutrient intake[40], lack of sensitivity/precision for specific nutrients e.g. protein and cholesterol[32], or fats[40], or low precision in certain population groups[25]. These FFQs typically contained stand-alone, low sensitivity PSEE with 1-3 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[86]. Some food photographs[29,38] showed good comparability to 24 h recalls or food records although in some cases the sample sizes were small and performance varied by ethnic group, sex, BMI and education level[26]. Estimates from food models used as stand-alone tools to assist in FFQs were comparable to other estimates for micronutrient intake but underestimated energy intake[34]. Combination tools were generally successful for dietary assessment of groups, to rank individuals across levels of intakes[31,36] or to detect changes during health promotion interventions[30] but not so sensitive for individual assessment. Although combined PSEE generally compared well against 24 h recalls systematic error and bias were an issue misclassifying up to 10% of individuals in some studies[31]. In general, adding volumetric tools such as food models, everyday objects and household utensils to semi-quantitative FFQs or food records improved comparability to calibration reference methods[34-36,87] although effective validity could not be established. The same happened for household utensil measures combined with other tools as part of 24 h recalls[3,87] and in food

records used as reference methods[33,35,36] (details in **Table 2**; **Table 5**, and Supplementary Table S2).

Group 2 papers

There were 22 eligible publications in native populations across a total of 9 countries and describing 20 different PSEEs (**Table 3** and Table S4 in Supplementary Information). The studied populations were adult Africans (from South Africa, Burkina Faso, Cameroon, Nigeria); Caribbeans (Jamaica); Irish adults and children; Indian and Bangladeshi children; and Sri Lankan adults and children. Both rural and urban settings were proportionally covered. Seven of the PSEE were tested in children only. The most common PSEE were combination tools, most of which included household utensil measures, followed by other volumetric tools (**Fig. 2a**).

Seven of the PSEE were used in 24 h recalls, while the rest were designed to develop or be used in FFQs or food records (except for five PSEE where a specific dietary instrument was not specified). Only four PSEE had been fully validated vs. actual weights and only two vs. weighed food records, however this represented a higher proportion than seen for Group 1 studies (**Fig. 4a**). A comparison study[52,67] used food scales alongside other PSEA but did not measure accuracy. Tests of agreement, sensitivity analyses and other tests excluding reproducibility and piloting were reported for 27% of the PSEE, (vs. 15% in Group 1), while piloting/reproducibility was only reported for 23% of the PSEE (vs. 50% for Group 1). Similar to Group 1, 55% of the PSEE in this group where 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, that is, in some cases photographs and diagrams worked better for shaped food compared to volumetric tools while in other studies it was the opposite. For example, the food atlas for South-Africans from Venter *et al*. produced a significantly higher percentage of

correct responses for solid foods (77%) than for amorphous foods (63%) (P <0.0001)[18]. However, line diagrams worked better in defined shape foods (e.g. fruit pieces) while photographs were more accurate in amorphous foods (e.g. curries, cooked vegetables) in another study comparing stand-alone vs. combined PSEE in Sri Lankan children[57]. Also, Lanerolle *et al*.[11], showed that food models in three portion sizes correlated highly with actual weights and Bland-Altman limits of agreement were relatively narrow between methods but this applied mostly to the six amorphous foods tested (including noodles, rice, curries, pureed vegetables and salad), while 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 over-reporting during dietary assessment and this applies to minority ethnic groups as well[6]. Using extensive systematic searches this review has identified and categorized 42 PSEE applied to immigrant minority ethnic groups as well as native individuals in the country of origin beyond the UK, covering a wide range of techniques and populations. Across all studies combination tools were the most common (47% of PSEE) followed by similar proportions of one-, two- and three-dimensional tools. Contrary to the trend seen in developed countries[12,88,89] 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 PSEE were designed to assist with portion estimation either in FFQs, 24h recalls and food records (36% for FFQ 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

Beyond the wide range of tools, the main finding from this review was the lack of strictly validated tools (i.e. vs. actual weight or weighed food records), with only 17% (7 PSEE)

reporting such measures, confirming earlier work in non-ethnic groups[8]. Attempts to calibrate a PSEE by comparing it with tools that produce other estimates were more common (31%), however systematic error cannot be ruled out from such comparisons (a strong correlation does not mean the methods necessarily agree). Tests of agreement were only reported for 3 PSEE. A larger proportion of the PSEE especially combined PSEE included components that had been previously validated or calibrated (45%). However such tests had been sometimes performed in a different population[41,54] and with a considerable time gap elapsed vs. the current application[38,45] which would affect applicability to the group it was intended to be used with[19,90].

PSEE effectiveness *per se* was difficult to ascertain, as in many cases the portion size evaluation component had been validated within the corresponding dietary assessment instrument (e.g. FFQ, 24 h 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 amorphous[11,18,57], and individual characteristics such as habitual portion size[17] and education further influenced results[17,18,67]. Also a number of tools were only tested in children, women, elderly adults or students and their efficacy in other population groups remains to be established. In cases where reliability was tested it tended to be moderate to high (correlation coefficients ranging from 0.4 to 0.9) but not consistently. Beyond food scales and measuring jugs[52], the best reproducibility was seen for food atlases[18], one combined PSEE including measuring tape and measuring cups[58] and portion lists in FFQs[25] and other questionnaires[30]; however stand-alone food photographs[52,67] and portion size fraction lists[40] were less reproducible. This may be due to the increased difficulty in conceptualising volumes when using PSEE that do not offer an absolute or relative measure for comparison vs. 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], and the influence of food and subject characteristics[17,91], the concept of a serving size may not exist in some cultures,

especially those who eat from a communal serving dish[6]. Tools able to assist in estimation of communal servings are thus very relevant. Some of these instruments were identified in studies conducted in the country of origin, including food photographs[17,18,61]; line-drawings[57] household utensil measures[55] amount of food prepared/leftovers[56]; and combination of these[57,58].

In an attempt to increase estimation accuracy combination tools were applied to FFQs and other instruments that typically produce under or overestimates. Combining one-, two- and three-dimensional components accounts for variation between the different types of foods and has the potential to increase accuracy of portion size estimation when these tools are applied across the range of foods and so has been recommended for individual dietary assessment[6,13]. While the potential effectiveness of such tools was highlighted in several of the identified studies[3,34-36,54,57,87] in most cases comparisons were made against other estimating tools and validity for combined PSEE was seldom demonstrated[57].

As previously suggested[8,10,45] the number of portion options in questionnaire-based PSEE, number and size of photographs in food atlases and type of tool (e.g. two- vs. three-dimensional) were all important factors affecting PSEE performance. For example, several of the PSEE identified used the Block FFQ[45] as a basis which incorporates three categorical size estimates as a tick option to be compared against a reference 'medium' portion size shown in ounces, size (e.g. 'medium'), household measures or natural units, derived from NHANES II data[36]. While the inclusion of the 3 portion size options resulted in higher correlation for energy, fat, percent calories from fat, and vitamins A and C when compared to a 24 h food record, vs. including only the NHANES median portion size, the reference medium portion descriptions are still prone to subjective interpretation. Specifically the use of household measures may reflect measurement convenience and approximation rather than a behavioral truth plus 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 utensils in the house

and use this information in subsequent assessments[5]; to produce ethnic specific utensil guides[3]; or for individual assessment, using the number of people in the household and the proportion of food taken from the total prepared[6].

Regarding the number of photographs in photographic series, including three 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[53]. Nelson *et al*. found that a series of 8 photographs was associated with smaller errors of estimation compared with a single one and this was incorporated into their food atlas[10] however this increased atlas complexity making it not practical for large epidemiological studies. As for food models, applying these alongside portion size open ended questions 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 component[45]. However no studies in this review demonstrated validity in this context. The only study where calibration of food models as part of an FFQ was attempted[31] suffered from systematic error by including the models both to calibrate the FFQ and as part of the calibration reference method.

User acceptability of the PSEE is important for continued application, however this was seldom reported. Food scales and measuring jugs were the least preferred tools in a study comparing a wide range of PSEA in Irish adults[52], who also rated household utensils as the easiest to use and most likely to be used in future, albeit being the least precise. It is likely that PSEE involving the need for numerical calculations[52], volume conceptualisation[10,92] or prolonged time due to complexity or size (e.g. food atlases)[52,53] may present barriers to implementation. In such cases more culturally appropriate tools accounting for customary ways of serving and eating may need to be considered.

Highlights from Group 1 studies

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

Many of the PSEE used in related immigrant populations outside the UK were similar to those used in the UK (e.g. including combinations of image and list-based PSEE), however they may need adaptation for application in the UK especially around commercial portion sizes. 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 is simple to use and has been applied in diabetes and metabolic syndrome education although is not validated (P Brauer, *personal communication)*; and 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 food to other food in the dish. Another potentially adaptable PSEE was the Chinese version of the Diet Habit Survey[82] which quantifies usual amount of spreads on bread with descriptors such as "lightly spread (can see the bread through it)"; "scrape (can barely see the spread)"[30], plus allows the conversion of household utensil amounts and commercial drinks into volumetric units (SL Connor, *personal communication*). Some of these components may facilitate understanding in first generation immigrants although they are subject to personal interpretation and may require numeracy skills[41].

Highlights from Group 2 studies

There was a relatively wide range of PSEE identified in the countries of origin which may be applicable to immigrant populations elsewhere and that provide useful insight especially on

feasibility and cultural acceptability of the PSEE. PSEE in this group typically contained low cost, culturally appropriate components such as local household utensils or everyday reference objects. Food photographs and food models were also frequently used especially in deprived areas. Results from studies in Sri Lankan children suggested that a combination of PSEA including life-size representations of traditional foods is probably more suitable than using a single stand-alone tool in that population. However a wider range of food types needs to be explored with such tools as performance depended heavily on texture, without a consistent pattern seen across studies (i.e. some favouring food picture-based PSEE for defined shape foods[18,57], and food models for amorphous food[11]; while others showing the opposite[57]). Household utensils on the other hand were the least precise and least accurate in at least two studies[52,57], as seen for some Group 1 studies[5,32]. While simple instruments may be suitable for low-literacy groups or those not speaking the language of the host country, may be non-intrusive and quick to complete, limitations in the validity and reproducibility of such tools needs to be considered. Specifically several studies[54,62,67] compared PSEE against estimates rather than actual weights; some of the studies tested a limited number of foods, portion options and individuals, or used low precision instruments[11,17,53,56]. 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[35,78].

Finally, many Group 2 studies included information on typical serving sizes, traditional utensils and foods commonly consumed from a shared dish, in addition to portion size information (e.g. references[55;17,73]), all of which may be useful when adapting existing dietary instruments to minority ethnic group populations.

Comparison to 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 PSEE tended to be

one-dimensional (e.g. lists of average portion sizes), used with or without visual aids[25,34,40], which were added with the aim of increasing specificity to capture the diets of the differing groups within each ethnicity, without differential bias for ranking individuals with regard to 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 non-computerised visual aids and 50% applied previously identified serving sizes in target ethnic groups. In the group of studies in original countries, household utensil and everyday objects were typically used. These can be easily bought in the community, are cheap and simple to apply and may explain their widespread use in low resource countries.

The lack of a consistent pattern on the impact of food texture on PSEE performance also confirms previous findings[15,17,52], suggesting that estimation accuracy may interact with other uncontrolled factors such as participant's experience and level of attention, willingness to cooperate or education[17,52]. A study in British adults comparing photographs to weighed foods reported less accuracy with estimating French fries, mashed potatoes and spaghetti than cornflakes[93] while a study in Norwegian children[94] found that mashed potatoes, and cornflakes in addition to other both shaped and amorphous foods were the best estimated foods. A third UK study using single portion food photographs 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 (e.g. estimation of food 5 min after consumption vs. on the following day or later), and none of the studies focused on minority ethnic food.

Regarding nutrient estimation accuracy, a previous review[19] suggested that mean intakes from FFQs may be higher than intakes estimated using reference methods (e.g. 24 h recall), 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 sub-groups[25,34]. Even in instruments adapted to be ethnic-specific, misreporting was an issue[35], and associated with higher overweight rates especially in women[54]. Overall, as many of the studies examining nutrient intakes used estimates as comparators it is difficult to ascertain the PSEE efficacy in this aspect confirming that validity, sensitivity and specificity still need to be considered even when the PSEE was previously tested in an ethnic minority population.

In relation to study populations, the South Asian community was also a common target group in a previous review of European immigrants[6] (20% of studies) 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 covering this aspect[31,41]. One such tool, the Oslo Immigrant Health Study[41] includes an index of dietary integration alongside questions on availability, cost and quality[95], and can thus be used as a cross-disciplinary tool to investigate how demographic and socio-cultural factors may modify food habits in minority ethnic groups.

Strengths and limitations of this review

Previous reviews have highlighted the importance of accurate portion size estimation for both population and individual assessment in ethnic minority groups[6,19,90] however, the portion size estimation element was not specifically addressed. The focus of the present review was 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 (e.g. Polish). However considerations related to instrument versatility, validity, specificity and to method development are likely to apply. A meta-analysis on the relative effectiveness of each instrument was not performed due to measures of error not always reported in all the studies however it would be worth exploring

this in future. Three Irish studies were included because the Irish were identified as a UK minority group from census data. However these studies sometimes used UK portion reference schemes[69] and similar foods to those traditionally consumed in the UK. Therefore information about the PSEE from the Irish studies may not be relevant to certain ethnic minorities. In addition, above 75% of the PSEE described here were applied across various age and sex population groups, but some were only tested in women, children, first or second generation migrants, affecting their general application. Differences may also result due to using a controlled environment[11,15,39,52] as participants might have been more aware of their portion size than in day-to-day situations and increased attention to portion size. Finally, while portion size has been recognised as a growing contributor to variation in intakes in recent years, frequency of consumption continues to be the major cause of variation[96,97]. It is therefore important to make sure that errors associated with portion size estimation do not mask true variability in portion size.

Conclusions and recommendations

Accurate assessment of ethnic diet portion sizes and intake requires considerations around the use of portion size estimation elements, food lists, and food composition databases[6]. In regards to portion size, this review identified 5 main areas to consider for these groups (**Table 6**). The PSEE needs to allow enough flexibility in the estimation of native, traditional recipes and ways of serving and eating. Assessment may be improved by the use of combined PSEE especially for diets where staple amorphous foods are common (e.g. rice, cous-cous). However the validity of any combined PSEE needs to be established beforehand, especially the selective application of each component by food type as 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 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 photographs and to adapt the PSEE

accordingly in future assessments. If a list of reference portion sizes is used for example in an FFQ, 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 these may not correspond to those typically consumed by related minority ethnic groups elsewhere due to acculturation. Investigation in the host country may still be necessary, followed by validation against weighed data.

In summary, a variety of PSEE have been reported in South-Asian and other minority ethnic groups in the UK and in related groups elsewhere. Instruments that require low literacy levels such as household utensils, photographs and food models are commonly used but their efficacy has not always been demonstrated. For epidemiological studies, PSEA-assisted questionnaires save time and participant burden but may be limited in the number of portion size options, require participant conceptualisation skills and complex developmental stages to be representative of the minority ethnic group diet. The use of computerised portion estimation tools warrants full investigation as at present, virtually no studies have explored these tools in these groups, yet they may offer logistic advantages over traditional methods (e.g. wider reach). Validated instruments for groups where specific customary ways of eating exist (e.g. shared dishes, eating from hand) are particularly needed. Combined PSEE 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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Table 1. Description of research question components by Population, Interventions, Comparisons, Outcomes, and Study Designs: Systematic review on portion size estimation elements in ethnic minorities relevant for the UK.

Criteria	Description
Population	Minority ethnic populations living in the UK, including Asian, Indian, Pakistani, Bangladeshi, Chinese, Black, Caribbean, African, Arab, Polish, Irish and Gypsy; or the same/related populations studied elsewhere (e.g. USA; Europe); related populations studied in their original country (e.g. Sri Lanka)
Interventions	Any intervention where a PSEE is described that can be used to quantify dietary intake in minority ethnic groups; survey data
Comparisons	Other minority ethnic groups in the UK or elsewhere; autochthonous population in the UK 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 where a PSEE is described
Study designs	Any study design where 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, non-government organisation; PSEE, portion size estimation element.

Table 2. Characteristics of 22 portion size estimation elements identified across 20 publications referring to main minority ethnic groups in the UK, or related groups elsewhere (full details provided in Supplementary Tables S1-S3). Original questionnaires used in the development of specific ethnic FFQs are shown in brackets.

Population and PSEE	Description	Quality measures	Target group	Reference
1. African Americans and other ethnicities; FFQ (NCI-HHHQ/ Block modified, Block *et al*.)[45]	Semiquantitative FFQ with portion list options for 'small', 'medium' or 'large' based on subjective estimation vs. other men/women; modified to include ethnic & regional food choices	Compared vs. 24 h recall; reliability-tested	Specific for USA immigrants and native population	Mayer-Davis *et al*. 1999)[25]
2. African Americans 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 vs. 24 h recall	African American; Japanese American; Latino & White groups from Hawaii & Los Angeles	Stram *et al*. (2000) [26]
3. Afro-Caribbean British; Combined PSEE for FFQ	Combination of traditional Afro-Caribbean food models; stainless steel serving spoons, soup dishes and unit numbers e.g. 1 egg; 1 slice	Compared vs. BMR	British Afro-Caribbean, free living adults	Sharma *et al.* (2002)[27]
4. Arab population; Food Guide Dome	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 what a serving is	Not validated or otherwise tested	Arab people living in Arab countries or elsewhere	Musaiger (2012)[28]
5. Black Americans; 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]
6. Chinese Americans; Combined PSEE for Diet Habits Survey	Combination of portion lists, food models and list of sample foods (including amount). Original DHS used household utensils, natural units, oz. and qualitative descriptors[a] some matching USDA portion sizes	DHS validated in North Americans; reliability-tested	Chinese-American college students	Sun *et al*. (1999)[30]
7. Chinese American combined PSEE for FFQ (Willett adapted) (Willett *et al*.,1985)[50]	Combination of ref. portion size list plus open ended question for number of portions per dish; and actual size, traditional Chinese food models. Portion sizes chosen to match commonly consumed amounts (see entry under Nath and Huffman)[32]	Compared vs. habitual diet	Chinese American women from San Francisco	Lee *et al*. (1994)[31]
8. Cuban Americans;	FFQ including reference portion size list plus open ended question for	Compared vs.	Cuban American adults	Nath and Huffman

[a] 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 (SL Connor, *personal communication*).

	FFQ (Willett) (Willett *et al*.,1985)[50]	portion size of non-listed foods. Portions based on customary portions[46] natural units (e.g. 1 slice of bread); household units and from authors' experience	estimated food records	residing in Miami	(2005)[32]
9.	Indian British; Combined PSEE for 24 h recall	Combination of food models for meat pieces and chapattis (3 sizes); and household utensils. Specific questions used for shared meals, e.g. cooked to serve 10-12 people	Household utensil component previously validated and reliability-tested	Pregnant women from India living in UK (2nd-3rd trimester)	Eaton *et al*. (1984)[33]
10.	Indian British; Food scales for food record	Table compression scales or hand-held extension spring scale used, plus accompanying utensils (e.g. measuring jug)	Validated (based on referenced protocol)	As above	Eaton *et al*. (1984)[33]
11.	Multi ethnic groups; Combined PSEE for FFQ (Block modified) (Block *et al.*)[45]	Combination of portion size options i.e. 'small', 'medium' or 'large' based on a reference portion; and food models. Reference portion set as the median gram weight of portion sizes in NHANES II, with 50 percent of the medium defined as small and 150 percent as large	Block FFQ previously validated	Block questionnaire designed for US; current version modified to include Japanese and Chinese ethnic foods	Hu *et al*. (2009)[34]
12.	Pakistani & White Europeans[b] Combined PSEE for food record	Combination of household measures, volume models; pack 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, UK	Vyas *et al*. (2003)[35]
13.	Pakistani & White Europeans; Food models for FFQ[c]	Food models	Compared vs. BMR	Pakistani and White European migrants living in central Manchester, UK	Vyas *et al.* (2003)[35]
14.	Puerto Rican Americans; Combined PSEAs for FFQ (Block modified) (Block *et al.*)[45]	Combination of open ended question for portion size in FFQ; NASCO food models[51] and household utensil volumes. For foods coming in natural units, number of units was also used. Assumed portions for models are based on USDA	Compared vs. 24 h recall; piloted	Puerto Rican, may be adaptable to related groups in UK	Tucker *et al*. (1998)[36]
15.	SA and Italian British; Food scales for food record	Weighed 7 day food records, complemented with household measures	Gold standard	Free-living, immigrant and native women from the general population of Greater Glasgow, UK	Anderson *et al*. (2005)[37]
16.	SA British; Food photographs (section	8 colour photographs of traditional SA foods/dishes from Nelson et al., 1994, 1996[d] on everyday crockery. For non-traditional foods, average	Not validated (estimates	Women from SA ethnic minorities living in the UK	Kassam-Khamis *et al*. (1999)[38]

[b] 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]

[c] As above.

	of food atlas)	portion sizes derived from MAFF (1994)[10],based on Gregory et al. (1990)[48]	compared vs. food records collected 2 years earlier)		
17.	SA British; Food photographs for FFQ and 24h recall	Colour photographs of 10 traditional SA foods and dishes	Validated vs. weights	UK SA community (Indian and Pakistani mothers and children)	Husain and Khokhar (2011)[39]
18.	SA British; Food scales for food record	Weights compared to standard MAFF portions (Crawley, 1988)[47]	Not validated	UK SA community only	Karim (1997)[43]
19.	SA British; Serving spoon and table spoon portion size guide	Coding and portion size manual developed for SA foods using serving spoons and tablespoons commonly used by SAs (average weight of Tbspoon and serving spoon of various meat, vegetable and rice dishes)	Not validated	SA population living in the UK	Sevak *et al.* (2004)[3]
20.	SA Canadians; FFQ	Ethnic FFQs with portion size fraction list designed for SA and for Chinese immigrants in Canada	Compared vs. estimated food record; reliability-tested	SA, Chinese and European immigrants living in Canada	Kelemen *et al.* (2003)[40]
21.	SA Canadians; Portion size pictorial guide	Pictorial guide with drawings of traditional SA foods incl. measurements in inches, cups and natural units. Portion sizes derived from focus groups with SA community plus the literature. Based on Beyond the Basics tool[e].	Not validated	Specific for SA community	Brauer and Mian (2006)[42]
22.	SA Norwegians and other ethnicities; Health questionnaires	Weights & volume lists for beverages; units of bread; staples; sugar; includes question on proportion of the whole meal eaten as staple i.e. rice, chapatti, potatoes	FFQ validated in Norwegians; food habits questions piloted in one of the ethnic groups	Adult and children (15-76 y) Pakistani, Turkish, Sri Lankan, Iranian, Vietnamese immigrants living in Oslo	Norwegian Institute of Public Health (2005)[41]

Abbreviations: BMR = basal metabolic rate; CHO = carbohydrate; FFQ = food frequency questionnaire; NCI-HHHQ = National Cancer Institute Health Habits and History Questionnaire; oz = ounces; PSEE = portion size estimation element; SA = South-Asian; Tbsp. = tablespoon).

[d] Each set of 8 photos illustrates portion sizes ranging between the 5th - 95th percentiles of distribution of portion sizes observed in the British Adult Dietary survey from1990 (Gregory *et al.,* 1990)[48]. Dishes were photographed with crockery most commonly associated with that dish i.e. rice, meat, vegetable & bean curries on a plate, and dhal in a bowl.

[e] The Beyond the Basics tool is the main tool in Canada for teaching about the Exchange system approach to managing CHO, from which this pictorial guide was developed and subsequently applied for educating on the metabolic syndrome (P Brauer, *personal communication*).

Table 3. Characteristics of 20 portion size estimation elements identified across 22 publications conducted in native populations in their country of origin, excluding UK (full details provided in Supplementary Table S4).

Country & Population	PSEE	Study design	Quality measures	Reference
1. Bangladesh Children 1-11 year old with diagnosed rickets in rural and poor area	Combined PSEE (food scales for 24 h WFR; volume models; package information)	Observational study. Used traditional and local food and recipes, left-overs; breastfeeding	Evidence-based method; protocol followed for staged weighing; records double-checked by investigator	Ahmed (2014)[64]
2. Burkina Faso Rural women taking part in nutritional study (low literacy)	Food atlas for a 24hR (4 portion size photos for 8 food items)	Validation vs. actual wt, n=257; atlas portions based on 24hR.	55% accuracy rate; Moderate to good estimation for most foods but under- and overestimations detected in 5 out of the 8 foods; impact of education	Huybregts *et al.* (2008)[17]
3. Cameroon Adults from rural and urban sites	Combined PSEE for EFR and for 24hR, 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 portion size data	Similar utensils used in validation of final FFQ (see Mennen *et al.,* 2001[54], below), however limited information on food models and utensils	Sharma *et al*.(1996)[78]
4. Cameroon Adults of African origin from rural and urban sites	Combined PSEE 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 compared vs. 24h recalls and 4 day WFR 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)[54]
5. India Retrospective analysis of 1-2 year old children data (New Delhi, 1993-1994)	Simplified portion size assessment questionnaire for field observations (fraction of amount consumed vs. presented)	Validation vs. WFR for future use in field studies; n=128 children. Full data for 3 foods only obtained although 5 tested	Accounted for leftovers, spillage. Incomplete statistical analyses. Low precision and sensitivity Reliability not tested but measured previously[70]	Dhingra *et al.* (2007)[56]
6. Ireland Irish children (n=594 , aged 5-12 years), adolescents (n=441, 13-17 years) and adults (n=1274, 18-64 years)	Combined PSEE for online database (digital food scales, food packaging; Nelson's food atlas [76]; government publication[74]; local food shop menus; household measures; standard units, other)	Creation of online database for food portion sizes of 545 foods based on data from 3 national dietary surveys using WFR and EFR	Some components are validated tools. Sensitive as based on large amount of weighed data. Portions do not differentiate by eating occasion though	Lyons *et al*., (2013)[69]

[a] In the same paper the authors also report the development of an FFQ for Jamaicans living in Jamaica (see below under Caribbean Population), as well as Jamaica and Caribbean immigrants living in the UK (see Table 2 under Sharma *et al.,* 2002[27]; Vyas *et al*., 2003[35]).

7.	Ireland 500 Irish pre-school children (1-4 years)	Combined PSEE for 4 day WFR (food scales, food packaging; Young Person's food atlas [79]; household measures)	Creation of food portion sizes database for pre-school children. Direct (~85%) and indirect measures (~15%)	Some components are a validated tool. Sensitive as based on large proportion of weighed data (75% of the weights came from caregivers)	Giltinan *et al*. (2013)[65]
8.	Ireland 120 young residents of the island of Ireland (18-25 years), mostly 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 PSEA for difficult-to-estimate foods, to be used by choice, for particular foods	Several of the tools had not been validated (e.g. hand measures). Only PSEA relevant for Ireland were tested; qualitative data collected. Food scales and jug were the most precise and photographs the least	Pourshahidi *et al.* (2013)[67] later described in Faulkner *et al*. (2016)[52]
9.	Jamaica Adults from district Kingston	Combined PSEE for food record and for 24hR 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 portion size information	Similar utensils used in the validation of the final FFQ (see Mennen *et al*., 2001[54], below). Limited information on food models and utensils;	Sharma *et al*. (1996)[78]
10.	Jamaica Jamaican adults incl. rural and urban dwellers	Combined PSEE for FFQ with open ended questions and PSEAs (local household utensils, food models, measuring cups and measuring tape)	Comparison vs. 24hR 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 x 24hR and BMR however systematic error possible. High underreporting (esp. females)	Jackson *et a*l., (2001)[58]
11.	Nigeria Healthy adult men and women from urban settings	Combined PSEE for 24hR (household measures and food models). Portion sizes based on ADA[75] 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 but comprehensive list with average portion sizes (in wt) & serving sizes (in household measures) of traditional foods	Sanusi and Olurin (2012)[55]
12.	South-Africa North West region adults, mostly educated females	Food atlas for FFQ (3-4 portions for 37 foods and photographs of utensils)	Development and validation study vs. actual wt for 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 (77%) vs. amorphous foods (63%). Good reliability. Especially accurate for solid foods but not practical to carry around. See also reference[73]	Venter *et al*. (2000)[18]
13.	Sri Lanka Urban children 10-16 years	Graduated food model for 9 commonly consumed SA foods in 3 sizes (based on previous research)	Validation vs. actual wt (n=80 children) of graduated food models. Low sensitivity (only 3 three portion sizes used)	Estimated wt from models correlated well with actual wt; good method agreement. Good accuracy and precision especially for amorphous foods: all foods except fish: 50%; rice 85% accuracy. Impact of texture.	Lanerolle *et al*. (2013)[11]
14.	Sri Lanka High school children 10-16 years	Stand-alone and combined PSEEs (small and life-size photographs, life-size line diagrams and household spoons in three sizes). Portion sizes based on government[68] and other	Validation vs. actual wt (n=80 teenagers for 4 four PSEAs. Portion sizes derived from consumption studies. No test-re-test measures conducted	Accuracy rates: 48% (n=876) small photos; 57% (n=558) large photos; 64% (n=1271) diagrams. Household utensils had lowest accuracy (est. rate 0.6%, n=475). Combined PSEE of all four aids: 68.3% (n=3180). Diagrams produced fewest over-	Thoradeniya *et al.* (2012)[57]

		schemes[71,72,57]		/underestimates but not good for all amorphous food (photos better)	
15.	Sri Lanka 1029 adults aged 30 years and above from rural area	Household utensil units for 3 day EFR. Portions based on government guidelines[68]	Case-control study looking at the association between intake of beta-carotene from fruit and veg. 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)[59]
16.	Sri Lanka Nationally representative sample of 20,390 individuals (all ages), 4,747 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 food 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 (2003)	Central Bank of Sri Lanka (~2004)[63]
17.	Sri Lanka Sri Lankan adults from urban, rural and estate areas, varied ethnicity Development study n=482 Nutrient intake study n=463	Combined PSEE for 24hR (household measures, single portion food photographs, Nelson's food atlas [76] and Shahar's food atlas[77]	Development of a 90 item FFQ for Sri Lankan (Jaywardena *et al.*, 2012);[60] assessment of nutrient intakes in Sri Lankan adults (Jayawardena *et al*., 2014)[61]	FFQ pre-piloted in 25 subjects. Food list expanded based on producers, local experts and popular knowledge Shahar's food atlas[77] is an official tool in Malay covering >360 food items. May lack specificity as only 4 foods included. Cooking oil types not distinguished.	Jayawardena *et al*. 2012[60]; Jayawardena *et al.* 2014[61]
18.	Sri Lanka Sri Lankan adults from urban, rural and estate areas, varied ethnicity	Combined PSEE for FFQ (portion size lists for 85 food items with average portion plus photos of 4 foods in 3 portions	Validation vs.7 day WFR for previously developed FFQ (see Jayawardena *et al.* 2012)[60] in 77 adults (65% women)	FFQ slightly overestimated CHO (11.5 g/day) and fat (5.7 g/day) but correlated with energy, CHO, PRO, fat and fibre (r =0.17-0.47; all p<0.05). Methods showed fairly good agreement but may over/under-estimate CHO, fat and fibre	Jayawardena *et al.* 2013[66] later described in Jaywardena *et al.* (2016)[53]
19.	Sri Lanka Healthy elderly (n=200, aged >60 years) from mostly rural area	Combined PSEE (household utensil units for 24hR plus food serving photographs)	Comparison study for a food variety score (FVS), a dietary diversity score (DDS) and a dietary serving score (DSS) vs. MAR using 24hR data	The three dietary scores correlated with mean adequacy ratios (r=0.45-0.58; all p< 0.01). Sensitivity and specificity analyses run to optimise the use of DDS and FVS. Portion sizes improved score performance	Rathnayake *et al.* (2012)[62]
20.	Sri Lanka Women (n=100), 20-45 years from urban and rural areas	Household utensil units for 3 day EFR	Cross-sectional study on the link between dietary CHO, physical inactivity and central obesity, Sri Lankan housewives	No data on accuracy or validity. Able to detect associations between diet and central obesity markers	Rathnayake *et al.,* 2014[85]

Abbreviations: 24hR = 24 h recall; EFR = estimated food record; FFQ = food frequency questionnaire; MAR = mean adequacy ratio; PSEA = portion size estimation aid; PSEE = portion size estimation element; Tbspn = tablespoon WFR = weighed food record; wt = weight. *Accuracy rate* relates to the percent number of times a food's portion is estimated correctly, out of the total number of estimations.

Table 4. Characteristics of the study populations for the 42 published sources reporting a portion size estimation element relevant for UK ethnic minorities.

Study population	Number of portion size estimation elements	% (n=42)
General population (i.e. free-living healthy adults)[a]	34	81
Based on national survey sample[b]	11	26
Females only	9	21
Children <19 only	5	12
College and secondary school students	3	7
Pregnant women only	2	5
Internet-based	2	5
Participants of weight loss programme	1	2
U.K. immigrant population	10	24
U.S. immigrant population	7	17
Other immigrant population (Canada, Norway; Arabs)	6	14
Native country population	20	48

[a] Excludes college/secondary school students, participants in weight loss interventions, audience of internet-based tools and national survey sample.

[b] Includes the USA Second National Health and Nutrition Examination Survey (NHANES II)[45]; the USA Hispanic Health and Nutrition Examination Survey (HHANES)[80]; the British Adults Survey[48], the Irish National Pre-School Nutrition Survey[65], the Irish National Children's Food Survey, National Teen's Food Survey and National Adult Nutrition Survey (2008-10)[69] and the Sri Lankan Consumption and Finance Survey[63].

Table 5. Quality measures for the 42 portion size estimation elements (PSEE) identified in this review. *Absolute validity* refers to comparison being made against actual weight (such as when measured by investigators). *Relative validity* refers to comparison against weighed food records (by participant). *Comparison studies* are those where estimations obtained with the PSEE were compared with estimations obtained by other estimating methods (e.g. 24 h recalls, estimated food records and energy expenditure equations). *Other tests* include tests of agreement, sensitivity analyses, face validity, precision tests and qualitative questionnaires. For full description of PSEE and country of application see Tables 2 and 3.

Author	Portion size estimation element	Comp. Prev. valid. or gold standard	Absolute validity (vs. W)	Relative validity (vs. WFR)	Comparison study and Ref. method	Piloted/ test-retest	Other test	No measures reported	Based on primary data or previous research
Ahmed (2014)[64]	Combined PSEE	0	0	0	0	0	0	✓	✓ Previous research
Amarasinghe *et al*. (2013)[59]	HHU	0	0	0	0	0	0	✓	0
Anderson *et al.* (2005)[37]	Scales	✓	0	0	0	0	0	✓	0
Brauer & Mian (2006)[42]	Picture guide	0	0	0	0	0	0	✓	✓ Focus groups and literature reviews
Central Bank of Sri Lanka (2004)[63]	Average portion list	0	0	0	0	0	0	✓	✓ Consumption data
Dhingra *et al.* (2007)[56]	Portion size fraction list	0	0	✓	0	0	0	0	0
Eaton *et al.* (1984)[33]	Combined PSEE	✓	0	0	0	0	0	✓	0
Eaton *et al.* (1984)[33]	Scales	✓	0	0	0	0	0	✓	0
Gans *et al.* (2009)[29]	Food atlas	0	0	0	0	✓	✓	0	0
Giltinan *et al*. (2013)[65]	Combined PSEE	✓	0	0	0	0	0	✓	✓ Food weights (caregivers 78%; manufacturers 7%)
Hu *et al*. (2009)[34]	Combined PSEE	✓	0	0	0	0	0	✓	✓ Focus groups and 24hR
Husain & Khokhar (2011)[39]	Food photographs	0	✓	0	0	0	0	0	✓ Pilot data and literature
Huybregts *et al.* (2008)[17]	Food atlas	0	✓	0	0	✓	0	0	0
Jackson *et al.* (2001)[58]	Combined PSEE	0	0	0	✓ (24hR and BMR)	✓	0	0	✓ Weighed recipes
Jayawardena *et al*. (2012)[60]	Combined PSEE	✓	0	0	0	0	0	✓	0
Jayawardena *et al*. (2013)[53,66]	Combined PSEE	0	0	✓	0	✓	✓	0	✓ Producers, local nutrition experts; participants
Karim (1997)[43]	Food scales	✓	0	0	0	0	0	✓	0
Kassam-Khamis *et al.* (1999)[38]	Food atlas (section)	✓	0	0	✓ (FR) (*)	✓	0	0	0
Kelemen *et al.* (2003)[40]	Portion size options list	0	0	0	✓ (EFR)	✓	0	0	✓ 4 day food records and 24hR; data for oils
Lanerolle *et al.* (2013)[11]	Graduated food model	0	✓	0	0	0	✓	0	✓ Previous research

Lee *et al.* (1994)[31]	Combined PSEE	0	0	0	✓ (HD)	0	✓	0	✓ Interviews and observations
Lyons *et al.* (2013)[69]	Combined PSEE	✓	0	0	0	0	✓	0	✓ Food weights or manufacturer's info used in 46-86% foods
Mayer-Davis *et al.* (1999)[25]	Portion size options list	✓	0	0	✓ (24hR)	✓	0	0	✓ Expert advice, field data
Mennen *et al.* (2001)[54]	Combined PSEE	✓	0	0	0	✓	0	0	✓ Weighed recipes
Musaiger (2012)[28]	FGP daily servings	0	0	0	0	0	0	✓	0
Nath & Huffman (2005)[32]	Reference portion list	✓	0	0	✓ (EFR)	0	✓	0	0
NIPH (2005)[41]	Portion size options list	✓	0	0	0	✓	0	0	✓ Published research
Pourshahidi *et al*. (2013)[52,67]	Combined PSEE	✓	0	0	✓ (PSEA)	0	✓	0	0
Rathnayake *et al*. (2012)[62]	Combined PSEE	0	0	0	✓ (MAR)	0	✓	0	0
Rathnayake *et al*. (2014)[85]	HHU	0	0	0	0	0	0	✓	0
Sanusi & Olurin (2012)[55]	Combined PSEE	0	0	0	0	0	0	✓	0
Sevak *et al.* (2004)[3]	HHU measuring guide	0	0	0	0	0	0	✓	✓ Weighed recipes
Sharma *et al.* (2002)[27]	Combined PSEE	0	0	0	✓ (BMR)	✓	0	0	✓ 2 day food records
Sharma *et al*. (1996)[78]	Combined PSEE Cameroon	0	0	0	0	0	0	✓	✓ Weighed recipes
Sharma *et al*. (1996)[78]	Combined PSEE Jamaica	0	0	0	0	0	0	✓	✓ UK recipe data
Stram *et al.* (2000)[26]	Food photographs	✓	0	0	✓ (24hR)	✓	0	0	✓ 3 day weighed records
Sun *et al.* (1999)[30]	Combined PSEE	✓	0	0	0	✓	0	0	✓ Expert advice and previous research
Thoardeniya *et al*. (2012)[57]	Stand-alone & combined PSEE	0	✓	0	✓ (PSEA)	0	0	0	✓ Previous research and consumption data
Tucker *et al.* (1998)[36]	Combined PSEE	✓	0	0	✓ (24hR)	✓	0	0	0
Venter *et al*. (2000)[18]	Food atlas including HHU photos	0	✓	0	0	✓	✓	0	✓ Interviews and focus groups
Vyas *et al.* (2003)[35]	Food models	0	0	0	✓ (BMR)	✓	0	0	✓ Focus groups; recipes
Vyas *et al.* (2003)[35]	Combined PSEE	✓	0	0	0	0	0	✓	0

(*) Weighed food records collected 2 years earlier.

Abbreviations: 24hR, 24 h recall; BMR, basal metabolic rate (Schofield equations); EFR, estimated food record; FFQ, food-frequency questionnaire; HD, habitual diet; HHU, household utensils; MAR, mean adequacy ratio; NIPH, Norwegian Institute of Public Health; Comp. Prev. Valid., component previously validated; PSEA, portion size estimation aids; Ref. method, reference method (comparison study); W, actual weight; WFR, weighed food record.

Symbols: √, element reported; 0, not reported.

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

Area	Considerations
1 Validity	Whenever possible, choose a validated portion estimation instrument that has been compared vs. weighed data and also been tested for reliability in the population of interest. For new and existing tools, consider collecting information on customary portions by sex and age as well as traditional household utensil measures via interviews or food records.
2 Specificity	Consider using portion estimation instruments that allow flexibility in the estimation 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 (i.e. for example depending on texture or shape one may use photographs or food models).
3 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 photographs, 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 levels.
4 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 generation and acculturation stage).
5 Special considerations for FFQs	Reference portion sizes need to be representative of the ethnic minority group studied and not taken from the general population as distributions may be skewed. FFQs options to indicate larger or smaller amounts from a reference portion, or an open-ended question may be more accurate than including a single reference portion. If open-ended portion size questions are used, an accompanying aid such as photographs or food models may increase accuracy

Abbreviations: FFQs, Food-frequency questionnaires.

FIGURE LEGENDS

Figure 1. Search process 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]. Databases searched were: 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, PsychINFO, 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 Thesis On-line Service, University of Birmingham e-Thesis, University of Chester digital repository, Sociological Abstracts and EconLit.

Figure 2. Distributions of the 42 portion size estimation elements (PSEE) identified in this review. (a) By type of PSEE. (b) By dietary assessment instrument the PSEE was part of. 2a, *Lists* includes lists of weights or volumes such as in household utensil measures or units; categorical size estimates such as "small", "medium", "large"; fractions of a reference portion (e.g."1/2 typical amount"), and text-based package information. *Pictures* include stand-alone photographs, food atlases, diagrams and drawing/picture guides. *Volumetric tools* include household utensils, food models, food replicas, non-food reference objects (e.g. deck of cards), hands, pack demarcations, measuring tapes, measuring jugs and food scales. *Combination tools* are tools made of more than one PSEE applied within the same dietary assessment instrument. 2b, *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; *Question*., non FFQ questionnaires.

Figure 3. Portion size estimation elements by study population across the 42 publications analysed in this review. 3a: Population distribution across all studies. 3b: Population distribution across studies with South-Asians. 3c: Distribution of PSEE types by study population. Non-UK White European includes Irish, Italian and other European. Multi-ethnic population includes White American, Hispanic, Iranian, Japanese, Turkish, Vietnamese and Chinese. The total exceeds 42 as some of the tools were used in various populations simultaneously. PSEE included in lists, pictures and volumetric tools are as per Figure 2.

Figure 4. Quality measures reported across the 42 studies examined in this review. 4a: number of PSEE for which quality measures, no measures, related tests (e.g. test of agreement) and development information (e.g. component previously validated or tool based on previous research) were reported. 4b: proportion of techniques against which PSEE were compared in studies reporting absolute or relative validity, and in comparison studies (n=20). *GS*, gold standard.