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NUTRITIONAL ASSESSMENT

Development and validation of the FiberScreen: A short questionnaire to screen fibre intake in adults

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Abstract

Background: Health effects of dietary fibres are the topic of many studies. Eligibility criteria often include a certain fibre intake, which requires dietary screening during recruitment. However, dietary assessment methods are extensive and burdensome for both the researcher and participant. Therefore, we developed and validated a short questionnaire (FiberScreen) to screen fibre intake.

Methods: The initial five-item questionnaire assessed fruit, vegetable, whole grain, pasta/rice/potato and legume intake. The optimised FiberScreen included 18 items, which further specified intake of the above-mentioned categories, and included nuts and seeds. The FiberScreen was completed during two fibre promoting interventions. In Study A, participants without constipation completed the five-item FiberScreen and a food frequency questionnaire (FFQ) during screening ($n = 131$), and the 18-item FiberScreen and a FFQ at 3-month follow-up ($n = 87$). In Study B, 29 constipated participants completed the 18-item FiberScreen at screening and a FFQ during the first study visit.

Results: The fibre estimate from the five-item FiberScreen and the FFQ was moderately correlated ($r = 0.356$, $p < 0.001$). Importantly, the 18-item FiberScreen and FFQ, when data of both studies were combined, had a strong correlation ($r = 0.563$, $p < 0.001$). The 18-item FiberScreen had a lower fibre estimate compared to the FFQ ($\Delta = 1.2 \pm 5.9$ g, $p = 0.030$) but the difference was relatively small. Bland–Altman plots showed a good agreement between the questionnaires. Completion time of the 18-item FiberScreen was 4.2 ± 2 min.

Conclusions: The 18-item FiberScreen is a suitable short screening questionnaire for ranking the fibre intake of adults. The 18-item FiberScreen can help to reduce screening burden for both the participant and researcher.

KEYWORDS

comparability, dietary fibre, food frequency questionnaire, functional bowel disorders, questionnaire, screening

INTRODUCTION

The health benefits of dietary fibre have long been recognised: a high-fibre diet can reduce the risk of certain cancers, obesity, diabetes mellitus and cardiovascular diseases.[1–6] Moreover, dietary fibre can improve stool pattern by adding bulk and softening the stool, so that it passes the intestine more easily. An adequate fibre intake can therefore reduce the risk of developing stool complaints and the severity of for example constipation.[7–12] Constipation can affect a large part of the population, and the prevalence can vary between 5% and 20% depending on the definition used.[13–15]

[Correction added on 27 December 2021, after first online publication: Peer review history statement has been added.]

A daily fibre intake of 14 g per 1000 kcal is recommended in the Netherlands because of these known health-promoting effects, meaning 30 g for women and 40 g for men.[16] In Europe, fibre intake ranges between 16 and 20 g day^{-1} for females and 18 and 24 g day^{-1} for males, which is far below the recommendations.[17] Moreover, the majority of the population is not meeting the recommended intake for fruits and vegetables, which are important sources of fibre in the European diet.[18,19] Intervention studies have been performed to assess health effects of fibre in different study populations, or to improve intake of fibre or high-fibre food categories for prevention measures or treatment of for example constipation.[8,20–25] Eligibility criteria for these studies often include a low dietary fibre intake, aiming to have a window of opportunity for improvement of fibre intake towards the recommendations, which requires dietary screening in the selection process. Dietary assessment methods such as a food frequency questionnaire (FFQ) and 24-h recalls are often used during screening, although these are time consuming,[26–28] expensive and more elaborate than strictly needed for screening.[29] This places an unnecessary burden on both the participant and the researcher.

To date, several short dietary screening questionnaires for different purposes have been developed. Some screening questionnaires focus on dietary intake with respect to being at risk for a certain disease, such as obesity in children,[30] malnutrition in elderly[31] or cardiovascular disease,[32,33] and are not valid for screening for an adequate fibre intake in a healthy or constipated adult population. Other screening questionnaires have only focused on fruit and vegetable intake,[34–36] and thus are not capturing the complete fibre intake. One of the most frequently used screening questionnaires is the PrimeScreen, which was developed to evaluate diet quality from the assessment of several high-fibre foods such as dark green leafy vegetables, fruits and whole grain foods.[37] Although the PrimeScreen is a well-developed validated screening questionnaire to assess diet quality, it is not optimal for screening total fibre intake because some important high-fibre food categories such as nuts and legumes are not included.

Because a lower fibre intake and fluid intake is associated with an increased prevalence of constipation,[38] adults with and without constipation might have a different dietary pattern. Both populations are of interest for fibre intervention studies. Therefore, we aimed to develop and validate a fibre-specific screening questionnaire (FiberScreen) with a short completion time for adults with and without constipation.

METHODS

The development and validation of the FiberScreen was part of two previously performed intervention studies. In short, Study A was a single-blind randomised controlled trial to assess the effects of a personalised dietary advice on fibre intake compared to general advice in adults without gastrointestinal complaints. The study consisted of a 6-week intervention and a 3-month follow-up period,[39] and was performed between March and September 2019. In Study B, the effects of a personalised dietary advice on fibre intake and subsequent effect on constipation-related complaints in adults with constipation was investigated. The study had a pre-test post-test design, which included a 4-week run-in phase and a 4-week intervention phase, and was performed between August and November 2020. Both studies were approved by the Medical Ethical Committee of Brabant and conducted according to the Declaration of Helsinki. Written informed consent was obtained from all participants.

The development and optimisation of the FiberScreen

To develop and validate the FiberScreen, the fibre estimates from the FiberScreen were compared to those obtained from the FFQ in both Study A and B. The initial FiberScreen (Study A) consisted of five items which assessed the intake of fruit, vegetables, whole grain products (for example bread, breakfast cereals, crackers), pasta/rice/potatoes and legumes of the last 2 weeks (Table 1; see also Supporting information, Doc. S1). These food categories were included because they contribute the most to dietary fibre intake in the Netherlands.[19] A scoring system was developed to score fibre intake, which was based on fibre content in the Dutch Food Composition database, and frequency and amount of consumption in a reference population as assessed in the Dutch Food Composition Survey.[19,40] Points were summed and could range between 1 and 22: a higher fibre intake was reflected in higher points. Because median fibre intake of the Netherlands was estimated at around 60% of the recommendation,[18,19] cut-off levels for a relatively low fibre intake were defined at ≤ 13 points for females and ≤ 15 points for males.

Based on the performance of the five-item FiberScreen (shown in the results section), the FiberScreen was optimised to an 18-item questionnaire, which aimed to estimate fibre intake in grams instead of scoring points (Table 1; see also Supporting information, Doc. S1). The optimisation process was done in a qualitative practice-based manner in consultation with trained research dieticians and was based on the discrepancy between answers of the FFQ and five-item FiberScreen. Whole grain, pasta, rice and potatoes, and legume intakes were further specified; such as for types of product consumed, frequency and amount of consumption. For example, the category bread now recalled the number of days and slices consumed for white, brown, multigrain, whole grain and rye bread, aiming to obtain a more accurate estimation of bread consumption. Dried fruits, nuts and seeds were included in the FiberScreen as a result of the high fibre content,[40] which could greatly impact fibre intake when consumed. Portion sizes were estimated using natural portions or household measures, which were the same as in the FFQ. Instead of converting answers to points, answers were now used to estimate fibre intake in grams. The frequency of consumption was multiplied by the amount consumed, and

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TABLE 1 Overview of the items in the FiberScreen version 1 and 2

FiberScreen version	Food category	Number of items	Type of questions
(1) Five items	Fruit	1	Amount of fruit consumed per day
	Vegetables	1	Amount of vegetables consumed per day
	Whole grain products	1	Days per week of consumption of > 2 pieces of whole grain products per day. Included whole grain bread, crackers/biscuits, bars, whole grain breakfast cereals
	Pasta, rice, potatoes	1	Whether people chose whole grain options (whole grain rice or pasta, potatoes) or refined rice or pasta
	Legumes	1	Days per week legumes are consumed
(2) 18 items	Fruit	2	Amount of fruit consumed per day
			Number of days consumption of dried fruits
	Vegetables	1	Amount of vegetables consumed per day
	Whole grain products	5	For each type of bread (white, brown, multigrain, whole grain, rye); number of days consumed and pieces
		4	For each whole grain product (breakfast cereals, bran, crackers/biscuits or bars); number of days consumed and amount
	Pasta, rice, potatoes	3	For each category the number of days consumed. Categories:
			(1) Refined pasta, white rice, refined couscous
			(2) Whole wheat pasta, whole wheat couscous, bulgur, whole grain rice, quinoa
			(3) Potatoes
	Legumes	2	Number of days consumed and amount of legumes consumed
	Nuts and seeds	1	Number of days consumed

Notes: Number of items reflect the amount of questions per food category. Questionnaires can be found in the Supporting Information 1.

subsequently multiplied by nutrient estimates from the Dutch Food Composition database.[40] For each food category, the average fibre content in the Dutch Food Composition database was taken. For the calculation, a factor was assigned for each answer: for example ≤ 1 portion of fruit per day equaled a factor of 0.5, one portion of fruit equaled a factor of 1, two portions of fruit per day equaled a factor of 2, and so on. These factors were assigned for fruits, vegetables and amount of legumes, which were then subsequently multiplied by their fibre content. For foods in which frequency answers were not continuous, factors were an estimation of number of days per week, meaning 'less than once per week' had a factor of 1/7, '1–2 days per week' had a factor of 2/7, '3–4 days per week' had a factor of 4/7 and '5–7 days per week' had a factor of 1. These factors were assigned for dried fruits, frequency of legume consumption, and nuts and seeds, after which they were multiplied by the fibre content. For breads, whole grain products and pasta/rice/potatoes, no factors were assigned because the number of days was questioned. These foods were calculated by multiplying the number of days consumed (divided by 7 to obtain an estimation per day) times the amount and the fibre content. The fibre estimations from each food were then summed to obtain an overall rough estimation of fibre intake.

Study design

For Study A, the five-item FiberScreen was assessed during screening (T1), after which it was optimised. The 18-item FiberScreen was subsequently applied in the same study at the 3-month follow-up (T2). The FFQ and the FiberScreen were completed during the same week at both T1 and T2. For Study B, the 18-item FiberScreen was completed during screening and a FFQ was completed during the first visit of the trial (on average 33.5 ± 12.1 days later). The FFQ was the same in both studies, although it differed in mode of administration (Study A: self-administered online; Study B: face-to-face interview by trained researchers) (Figure 1). All versions of the FiberScreen were completed online. Completion time for the 18-item FiberScreen was assessed in Study B, but not in Study A.

The FFQ was a 247-item semi-quantitative meal-based FFQ that recalled habitual diet of the last month, which was based on and developed using a validated FFQ.[41,42] The same items from the validated FFQ were assessed but, because of the nature of the interventions in which we provided personalised dietary advice per mealtime to stimulate fibre intake, items of this FFQ were assessed per mealtime (breakfast, during the morning, lunch, during the afternoon, dinner, during the evening) instead

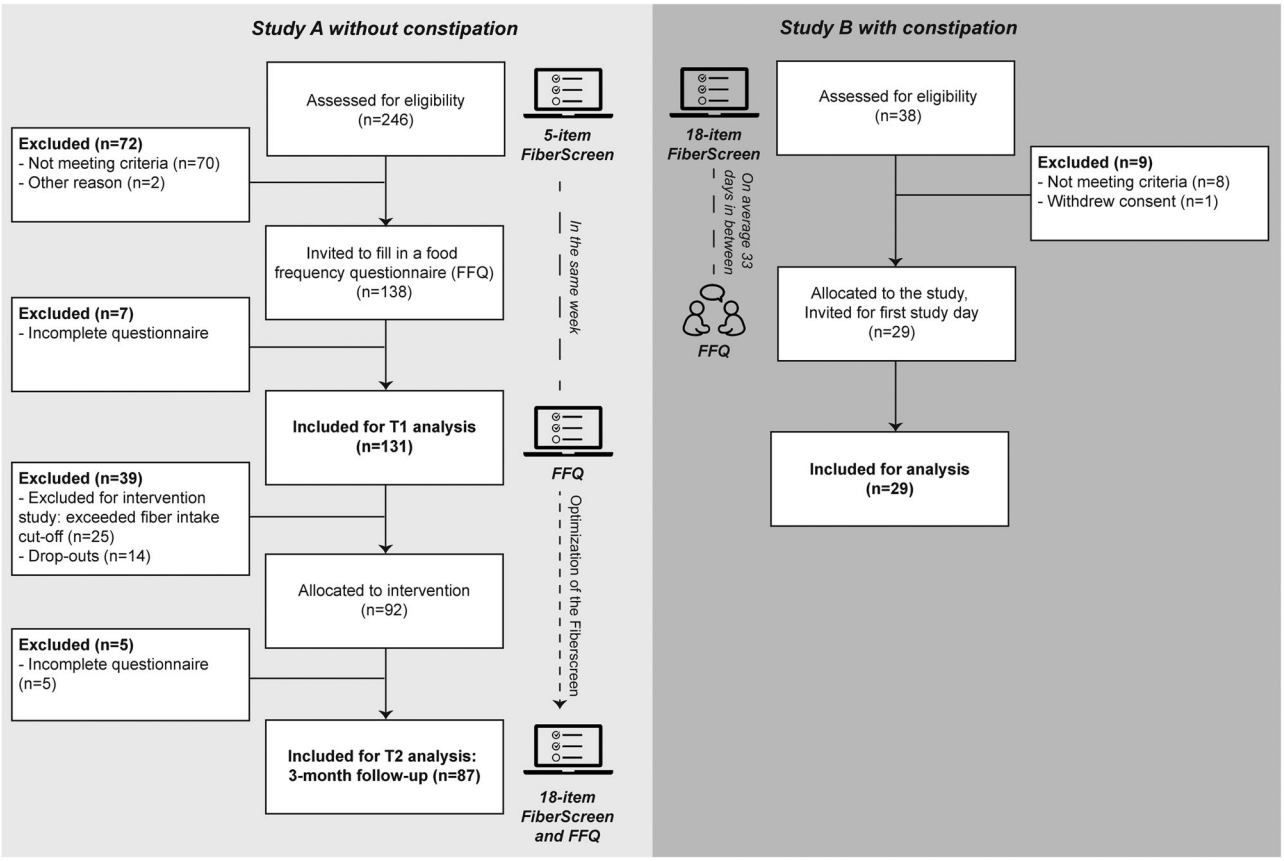

FIGURE 1 Design and participant flowchart of both Study A and B

of for the whole day. Selection of which item would be assessed at which mealtime was based on the Dutch Food Composition Survey.[19] Answers for each food ranged from 'never' to '7 days per week', and portion sizes were estimated using natural portions or household measures (e.g., one slice or one tablespoon). Nutrient intakes were calculated by multiplying the frequency of intake with the amount; nutrient estimates were obtained from the Dutch Food Composition database.[40]

Study participants

For Study A, eligible participants were older than 18 years, apparently healthy, in possession of a computer and mobile phone compatible with the applications, and living in the surroundings of Wageningen (maximum 50 km). Participants were excluded when they had a diagnosis of any digestive tract disease or frequent bowel complaints, cardiovascular disease, diabetes mellitus, any type of cancer, or renal disease, or were currently following a gluten free or weight loss diet and were unable or unwilling to change, were using diuretics, antidepressants, codeine, antibiotics or fibre supplements, or were currently pregnant or breastfeeding. For the intervention study, participants were eligible when having a fibre intake < 26 g for females or < 33 g for males (≥ 15% below the recommendation for fibre). In the current analysis, participants with a higher fibre intake at screening were also included. As shown in Figure 1, $n = 246$ adults were assessed for eligibility and $n = 131$ participants were included at T1, of whom $n = 87$ also completed the T2 measurement.

Study B had similar inclusion and exclusion criteria as Study A but differed on the following points: as a result of the Covid-19 pandemic, age was restricted between 18 and 55 years and body mass index (BMI) was <30 kg m^{-2}, to adhere to national Covid-19 guidelines. Furthermore, eligible participants had constipation-related complaints, which were defined as being unsatisfied with their bowel habit (< 6 on a visual analog scale from 1 'very unsatisfied' to 10 'very satisfied') and had a habitual stool of Bristol stool type 1–4 and/or a stool frequency ≤ 4 times per week.[43] In addition to the exclusion criteria listed for Study A, participants were excluded when having a depression or hypothyroidism, or using prucalopride, methylnaltrexone or linaclotide laxatives. As shown in Figure 1, $n = 38$ adults with constipation were assessed for eligibility, and $n = 29$ participants were included in analysis.

Statistical analysis

Data are presented as the mean ± SD or median (interquartile range) when skewed. For the 18-item FiberScreen,

analysis was performed both stratified per study and combining data of Study A and B. To assess relative validity, Pearson's correlation coefficients were computed between the items of the FiberScreen and the FFQ. This was carried out for total fibre intake and fibre intake per food category (fruit, vegetable, whole grain, pasta/rice/potato, legumes, nuts and seeds). Paired sample *t* tests were performed to compare differences between the fibre estimates of the 18-item FiberScreen and the FFQ. Furthermore, the agreement between the 18-item FiberScreen and the FFQ was visualised in Bland–Altman plots,[44] plotting the average intake versus the difference of the two questionnaires. Data was analyzed using SPSS, version 25 (IBM Corp.) and Prism, version 5 (GraphPad Software Inc.) $p < 0.05$ was considered statistically significant.

RESULTS

The demographic data of both studies show that participants in Study A at T1 were older, more often male and had a higher BMI compared to participants of Study B (Table 2). Energy intake was higher in Study A, although fibre intake measured by the FFQ was higher in Study B. Compared to the study population at T1 of Study A, the average age (48.2 ± 21 years) was higher at T2, although BMI (24.9 ± 4.0 kg m^{-2}) and the percentage of men (37%) remained similar. Completion time of the 18-item FiberScreen in Study B was under 10 min with an average completion time of 4.2 ± 2 min, which contrasts markedly with an estimated FFQ completion time of 45–60 min.

Initially, we started with a five-item FiberScreen to estimate fibre intake in Study A. At T1, the average score for the five-item FiberScreen was 8.5 ± 3.1 points compared to an average fibre intake of 22.6 ± 8.0 g estimated by the FFQ, which had a moderately strong correlation coefficient ($r = 0.356$, $p < 0.000$). For product categories, correlation coefficients were low to moderately strong (ranging between $r = 0.126$ and $r = 0.374$). Fruit showed the highest correlation coefficient and legumes the lowest (Table 3). Because we were not satisfied with the performance, the FiberScreen was further developed to an 18-item questionnaire to improve agreement between the FiberScreen and the FFQ.

Fiber intake was estimated to be on average 24.2 ± 6.0 g by the 18-item FiberScreen at T2 of Study A compared to 23.7 ± 6.6 g by the FFQ, which matched well ($p = 0.138$). For Study B, the 18-item FiberScreen estimated fibre intake to be 17.0 ± 3.9 g, which was significantly lower compared to the FFQ (24.2 ± 6.4, $p < 0.000$) (Table 4). When data of the two studies were combined, the estimate of the 18-item FiberScreen was significantly lower compared to the FFQ, although the difference was relatively small (Δ = 1.22 ± 5.9 g, $p = 0.030$). The estimate of the 18-item FiberScreen was significantly lower for all categories except legumes compared to the FFQ when the data of both studies were combined. Compared to the FFQ, the 18-item FiberScreen correctly classified 70 participants (81%) in Study A, 17 participants (59%) in Study B and 87 participants (75%) in both studies as having a relatively high or low fibre intake, when using the eligibility cut-off for the intervention studies (females < 26 g; males < 33 g of fibre per day).

Importantly, Pearson correlation coefficients with the FFQ were higher for the 18-item FiberScreen than for the five-item FiberScreen. In Study A, all categories at T2 had a significant correlation coefficient ($p < 0.001$) ranging between $r = 0.457$ and 0.731 between the 18-item FiberScreen and the FFQ (Table 3). Total fibre correlation was $r = 0.705$ ($p < 0.001$). The correlation of total fibre intake between the 18-item FiberScreen and the FFQ was similar in males and females. In Study B, total fibre correlation was $r = 0.590$ ($p = 0.001$) and all categories except legumes ($r = 0.178$, $p = 0.357$) had a significant correlation coefficient ranging between $r = 0.373$ and 0.684 ($p < 0.05$). After visual inspection, an outlier in legume intake in Study B was identified (FFQ = 7.95 g, FiberScreen = 0.82 g of fibre originating from legumes). When this participant was removed from analysis, the correlation coefficient improved significantly to $r = 0.454$ ($p = 0.015$). When data of T2 in Study A and B were combined, total fibre correlation was $r = 0.563$ ($p < 0.000$) and correlation coefficients for the subcategories ranged between $r = 0.249$ and 0.708 ($p < 0.05$), indicating moderate to strong correlations between the categories of

TABLE 2 Baseline characteristics of the participants included in the analysis

	Adults without constipation (Study A, T1, *n* = 131)	Adults with constipation (Study B, *n* = 29)
Age (years)	46.8 ± 22	33.2 ± 13
Body mass index (kg m^{-2})	25.1 ± 4.1	22.8 ± 2.4
Gender, *n*(%) of males	50 (38)	5 (17)
Dietary intake based on the food frequency questionnaire		
Energy (kcal)	2230 ± 680	2041 ± 425
Protein (en%)	14.7 ± 2.4	14.6 ± 2.1
Total fat (en%)	39.8 ± 4.1	37.6 ± 3.7
Saturated fat (en%)	14.0 ± 2.5	12.2 ± 2.1
Carbohydrates (en%)	39.5 ± 5.3	41.4 ± 4.8
Fiber intake (g)	22.6 ± 8.0	24.2 ± 6.4
Meets fibre recommendation in g, *n* (%)*	15 (11)	4 (14)
Meets fibre recommendation per 1000 kcal, *n* (%)*	6 (5)	5 (17)

Notes: Data are presented as the mean ± SD or *n* and %. Body mass index is self-reported.

Abbreviation: En%: energy percentage.

*Recommendation according to the Dutch Health council, for males 40 g of fibre or 14 g per 1000 kcal, and for females 30 g of fibre or 14 g per 1000 kcal.

TABLE 3 Pearson correlation coefficient between the FiberScreen and the 247-item food frequency questionnaire

	Adults without constipation (Study A)				Adults with constipation (Study B)		Adults with and without constipation (T2 Study A + B)	
	Five-item FiberScreen, T1		18-item FiberScreen, T2		18-item FiberScreen		18-item FiberScreen	
	Pearson's *r*		Pearson's *r*		Pearson's *r*		Pearson's *r*	
	n = 131	*p*-value	*n* = 87	*p*-value	*n* = 29	*p*-value	*n* = 116	*p*-value
Total dietary fibre (g)	0.356	**0.000**	0.705	**0.000**	0.590	**0.001**	0.563	**0.000**
Fruit (g)	0.374	**0.000**	0.707	**0.000**	0.684	**0.000**	0.708	**0.000**
Vegetables (g)	0.301	**0.000**	0.457	**0.000**	0.576	**0.001**	0.499	**0.000**
Whole grains (g)	0.241	**0.006**	0.603	**0.000**	0.587	**0.001**	0.593	**0.000**
Pasta, rice, potatoes (g)	0.144	0.100	0.505	**0.000**	0.418	**0.024**	0.479	**0.000**
Legumes (g)	0.126	0.152	0.731	**0.000**	0.178	0.357	0.660	**0.000**
Nuts and seeds (g)	Not assessed		0.469	**0.000**	0.373	**0.047**	0.249	**0.007**

Notes: Values indicate Pearson's correlations coefficient and *p*-values. $p < 0.05$ was considered statistically significant, indicated by the bold text. For the five-item FiberScreen, total dietary fibre and food categories received points for amount of fibre. For the 18-item FiberScreen, fibre content from each food category was tested.

TABLE 4 Differences between the 18-item FiberScreen and the 247-item food frequency questionnaire (FFQ)

	Adults without constipation (Study A, *n* = 87)		Adults with constipation (Study B, *n* = 29)		Adults with and without constipation (T2 Study A + B, *n* = 116)	
Total dietary fibre (g)	−0.77 ± 4.8	0.138	7.19 ± 5.2	**0.000**	1.22 ± 5.9	**0.030**
Fruit (g)	0.60 ± 1.7	**0.001**	0.51 ± 1.2	**0.026**	0.58 ± 1.6	**0.000**
Vegetables (g)	0.14 ± 1.5	0.388	1.28 ± 1.5	**0.000**	0.42 ± 1.6	**0.005**
Whole grains (g)	0.59 ± 2.9	0.062	1.93 ± 3.2	**0.003**	0.92 ± 3.0	**0.001**
Pasta, rice, potatoes (g)	−1.60 ± 1.2	**0.000**	−1.08 ± 1.1	**0.000**	−1.47 ± 1.2	**0.000**
Legumes (g)	0.27 ± 1.4	0.078	−0.00 ± 1.7	0.991	0.20 ± 1.5	0.148
Nuts and seeds (g)	−5.24 ± 2.1	**0.000**	0.06 ± 0.9	0.709	−3.91 ± 2.9	**0.000**

Notes: Results of a paired sample *t* test. Values indicate differences (mean ± SD), computed as FFQ—FiberScreen. $p < 0.05$ was considered statistically significant, indicated by the bold text.

the two questionnaires. Fruit showed the highest correlation coefficient and nuts and seeds the lowest.

The Bland–Altman plot revealed a good agreement between the 18-item FiberScreen and the FFQ including both Study A and B, although the 95% limit of agreement was quite wide (−10.5–12.9 g of fibre) (Figure 2a). The difference between the questionnaires remained stable when the average intake increased (ß = 0.002 ± 0.01, $p = 0.980$). No differences in the performance of the 18-item FiberScreen between males and females were seen ($ß_{males} = 0.07 \pm 0.16$, $p = 0.660$; $ß_{females} = -0.06 \pm 0.14$, $p = 0.680$) (Figure 2b). To assess the performance of the FiberScreen for the different sources of dietary fibre, Bland–Altman plots for the individual product categories were computed. The difference between the two questionnaires was dependent for the intake of fruit (ß = 0.54 ± 0.07, $p < 0.001$) (Figure 3a), vegetables (ß = 0.54 ± 0.10, $p < 0.001$) (Figure 3b) and pasta, rice and potatoes (ß= −0.63 ± 0.10, $p < 0.001$) (Figure 3d). The slope for whole grains (ß= −0.09 ± 0.10, $p = 0.353$) (Figure 3c), legumes (ß = 0.11 ± 0.08, $p = 0.190$) (Figure 3e) and nuts and seeds (ß = 0.22 ± 0.12, $p = 0.07$) (Figure 3f) was stable, meaning that the difference between the two questionnaires was not dependent on intake.

DISCUSSION

We developed and validated a short fibre screening questionnaire, called FiberScreen, against a meal-based FFQ in Dutch adults with and without constipation complaints. Overall, we have shown that dietary fibre intake as assessed by the 18-item FiberScreen has good comparability with a meal-based FFQ, regardless of gender. The 18-item FiberScreen had a short completion time under 10 min, which

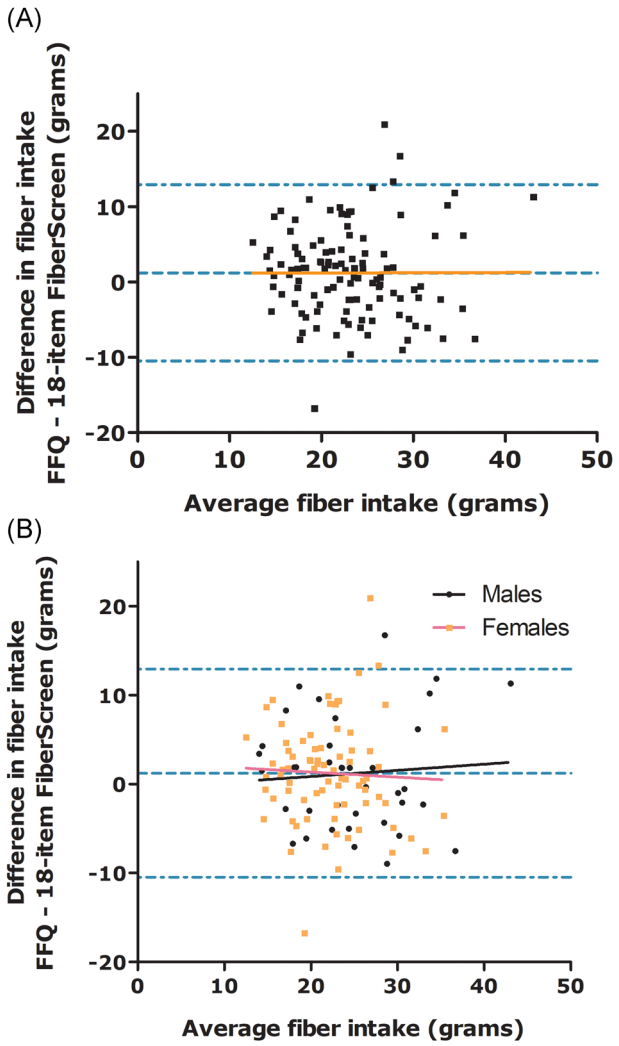

FIGURE 2 (a) Bland–Altman plot of fibre intake of both Study A and B. (b) Bland–Altman plot of fibre intake of both Study A and B, stratified for gender. Both plots show the difference of the fibre estimate between the food frequency questionnaire (FFQ): the 18-item FiberScreen on the *y*-axis versus the average fibre estimate of both questionnaires of the *x*-axis. The line represents the regression line

is considerably less than the estimated 45–60 min for the FFQ, thus reducing the burden for both participant and researcher.

Our questionnaire adds to the existing list of short screenings for dietary intake. However, to date, no specific dietary fibre screening questionnaire has been developed. Most questionnaires are developed to screen for being at risk of disease, such as malnutrition in elderly,[31] obesity in children[30] or cardiovascular disease.[32,33] Rifas-Shiman *et al.*[37] developed the PrimeScreen, a short dietary assessment questionnaire, which has shown relatively good comparability with a FFQ in 160 healthy adults. Total fibre correlation was $r = 0.58$, for fruit and vegetables categories, ranging between $r = 0.36$ and 0.70, and, for whole grain products, this was $r = 0.51$.[37] We found similar correlations for fruit and vegetables, although there was a stronger correlation for total fibre intake and whole grain products than PrimeScreen. Our higher total fibre correlation might be explained by the fact that PrimeScreen focuses on a short questionnaire to assess total diet quality and therefore lacks the inclusion of certain high-fibre categories such as legumes, nuts and seeds, and thus does not fully capture total fibre intake. The correlation for nuts and seeds in the present study was relatively low, and the difference between the 18-item FiberScreen and the FFQ quite large. Our nuts and seeds correlation coefficient is similar to a FFQ validation study that compared with 24-h recalls,[45] indicating that it is a difficult category to estimate. Previous screeners have not included nuts and seeds[30–33,37] but, as a result of the nutritional value and fibre content, it is an important category to include. Further work is needed to improve nuts and seeds intake estimation.

There was no significant difference in the fibre estimate between the 18-item FiberScreen and the FFQ in Study A (T2), although there was a significant difference in Study B. Possibly, participants in Study A were better able to estimate their fibre intake at T2 because they already received a targeted high-fibre intervention and had already completed the FFQ once at T1. Moreover, as a result of the study design of Study B, there was approximately 1 month between the completion of the 18-item FiberScreen and the FFQ. Participants might have changed their diet in between, especially with the prospect of having a face-to-face food interview. Research has suggested that a small dietary intervention can already instigate behaviour change,[46] or change responses to a self-administered questionnaire.[47] However, the FFQ recalled dietary intake from the last month; therefore, it includes the time period of the 18-item FiberScreen. Furthermore, participants of Study B were blinded at that time for the goal of the intervention, namely fibre intake; thus, it is unlikely that filling in the 18-item FiberScreen affected their fibre intake. It remains speculative whether this time difference could have caused the difference in performance of the 18-item FiberScreen. It is unlikely that the difference in mode of administration caused the difference between questionnaires because previous research found little discrepancy in dietary intakes assessed via self-administered web-based 24-h recalls versus interview-administered 24-h recalls.[48] When the data of the two studies were combined and thus a larger sample size with more variation was acquired, there was a significant difference of 1.2 g of fibre between the 18-item FiberScreen and the FFQ. However, this is a relatively small difference compared to the average total fibre intake of approximately 24 g in both studies. Furthermore, because fewer items are assessed in the 18-item FiberScreen compared to an extensive FFQ, a lower estimate can be expected. Because the FiberScreen is not developed to measure absolute fibre intake, but to screen for a relatively low or high fibre intake and rank participants, researchers should keep this in mind when using the FiberScreen because it is not suitable for a complete dietary assessment. The 18-item FiberScreen was able to accurately identify approximately 75% of the study

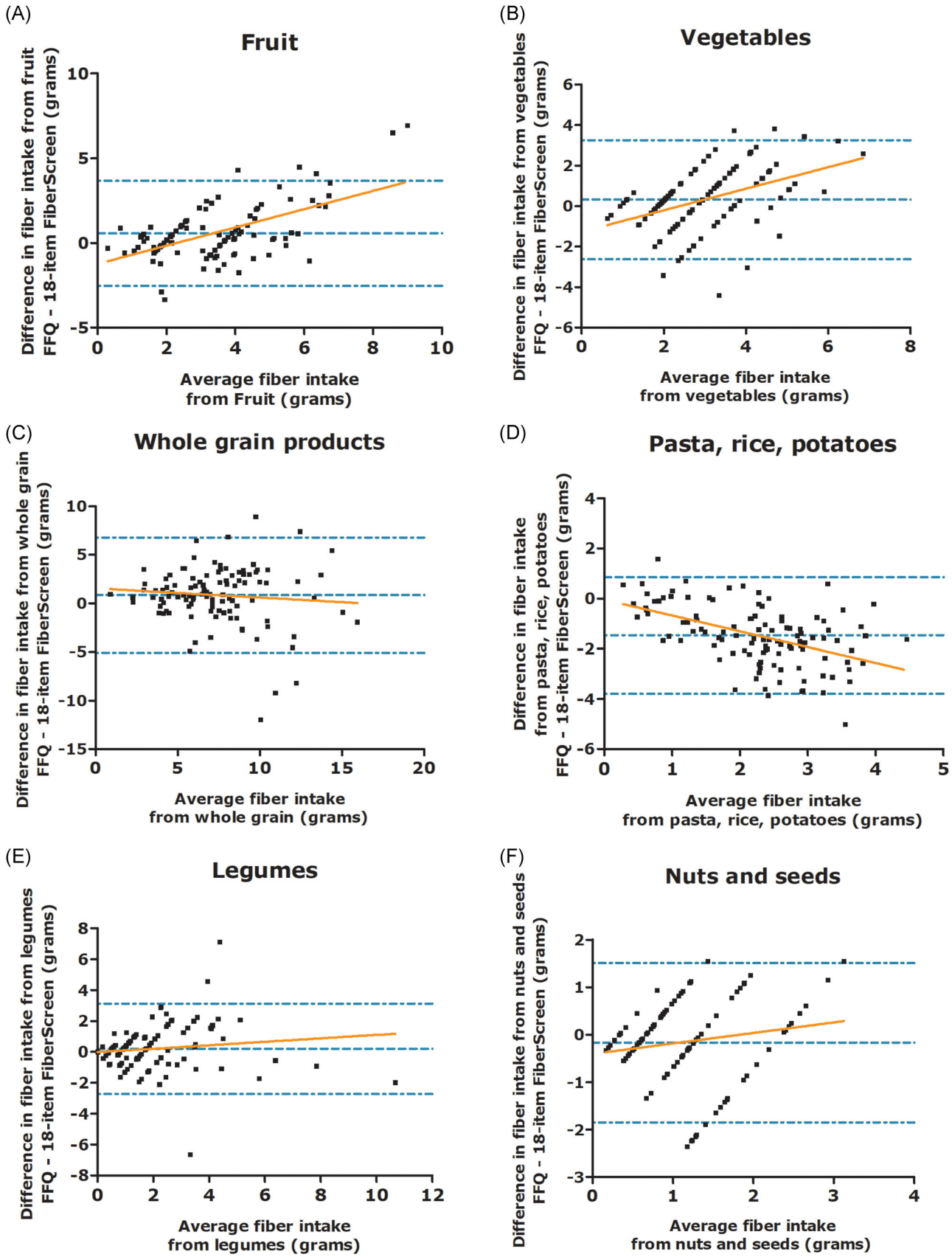

FIGURE 3 (See caption on next page)

population as having a relatively low or high fibre intake, based on our intervention study cut-offs. Thus, when using the FiberScreen, a larger screening sample needs to be taken into account, after which a complete dietary assessment method can be completed. This approach would result in a lower burden for more participants and researchers.

The items selected for the FiberScreen were based on the contribution of foods to fibre intake as assessed by previous literature, which has shown that cereal and cereal products (43%), vegetables (14%), potatoes and other tubers (10%), and fruits, nuts and olives (11%) are the main sources of dietary fibre in the Dutch diet.[19] By assessing these food categories and including some additional high-fibre categories such as legumes, we were able to limit the FiberScreen to 18 items. As a result of the item selection, the FiberScreen is validated for a Dutch adult population or population with similar dietary pattern, although it needs further validation before it can be used in a population with a different dietary pattern. The same methodology can be applied, although it needs to be adapted for the dietary pattern of that specific population. For example, bread or potatoes might be less consumed in other populations and the current FiberScreen might miss important local products. Furthermore, the fibre estimate from the 18-item FiberScreen is now calculated with the Dutch Food Composition Table[40] and, for usage in other countries, it would be beneficial to use a local food composition tables for a more accurate estimate.

In the present study, we used the FFQ as a validated comparison method; however, the FFQ is not without limitations because it can be prone to recall bias as a result of the longer recall period and can be susceptible for socially desirable answers. However, this is a problem for all type of dietary assessment methods and not specific only to the FFQ.[49] An FFQ is not validated to measure absolute dietary intake but is designed to rank intake of participants.[27,49] Furthermore, an FFQ is strengthened by the fact that is recalls habitual diet over a longer period of time, and therefore circumvents recent changes in the diet, such as a result of illness.[28] Because the FiberScreen is developed to screen participants' eligibility for trials based on habitual diet, ranking participants is sufficient, and therefore the FFQ can be seen as a valid reference method for the validation of our FiberScreen. Ideally, it is best to use a biomarker as reference in validation studies, although, for dietary fibre, no valid biomarker is currently known.[28,49] Some have suggested plasma alkylresorcinol as a biomarker for whole grain or rye intake,[50–52] although it has shown poor correlations with total fibre intake and other grain sources,[53] thus limiting its use.

This validation study is strengthened because it adheres to most key guidelines proposed by Serra-Majem *et al.*[54] regarding sufficient sample size (> 100), and uses different statistics to assess validity, such as the comparison between questionnaire means, correlations and agreement via Bland–Altman plots. Furthermore, the 18-item FiberScreen was tested in two separate populations, giving a good overview regarding its validity. Therefore, even though assessment of dietary intake and the validation in the present study is not without limitations, the analysing methods and sample size holds enough power for sufficient validation of the 18-item FiberScreen. Future studies should include further testing of the 18-item FiberScreen in different populations and include a broader range of fibre intake, aiming to further strengthen the validation. A large advantage of the FiberScreen is the low burden for both researcher and participant. Previous research indicated that an average FFQ completion is between 30 and 60 min[28]; for our lengthier meal-based FFQ, we estimated completion time to be between 45 and 60 min. When comparing the time burden with 24-h recalls, which is on average 40–45 min per digital recall or 20–30 min per telephone recall, the completion time of the FiberScreen of under 10 min is a great advantage. In addition to its use in research, the 18-item FiberScreen could also be of value in clinical practice, which could help give an approximate indication of fibre intake.

Future research needs to focus on portion size estimations, which are a major cause of measurement error in most types of dietary assessment.[55] Recent research has suggested that a text-based description of portion sizes is more accurate than image-based descriptions[56]; however, this conflicts with the conclusions of a recent systematic review.[57] This indicates the complexity of portion size estimation, and the need for more research. Furthermore, sustainably increasing dietary fibre intake remains a challenge because this is far below recommendations.[17,18] Recently, we have shown that a digital personalised dietary advice was effective in increasing fibre intake, even 3 months after the intervention.[39] Personalised dietary advice might offer solutions for instigating long-term behaviour change regarding the diet and fibre intake.

In conclusion, the 18-item FiberScreen is a valid short screening questionnaire for ranking the fibre intake of Dutch adults with and without constipation. The 18-item FiberScreen can be useful questionnaire enabling researchers to quickly estimate fibre intake during recruitment, thus significantly reducing the burden for both the participant and researcher during screening.

FIGURE 3 (a) Bland–Altman plot of fibre from fruits of both Study A and B. (b) Bland–Altman plot of fibre from vegetables of both Study A and B. (c) Bland–Altman plot of fibre from whole grain products of both Study A and B. (d) Bland–Altman plot of fibre from pasta, rice and potatoes of both Study A and B. (e) Bland–Altman plot of fibre from legumes of both Study A and B. (f) Bland–Altman plot of fibre from nuts and seeds of both Study A and B. All plots show the difference of the fibre intake from each food category between the food frequency questionnaire (FFQ): the 18-item FiberScreen on the *y*-axis versus the average fibre estimate of each food category of both questionnaires of the *x*-axis. The line represents the regression line

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AUTHOR CONTRIBUTIONS

IR collected the data, conceived and designed the analysis and FiberScreen, performed the analysis, and drafted the manuscript. NMdR was involved in study and statistical supervision, and critically revised the manuscript for important intellectual content. EGZ was involved in study and statistical supervision, and critically revised the manuscript for important intellectual content. NdW obtained funding, collected data, was involved in study and statistical supervision, and critically revised the manuscript for important intellectual content. BJMW was involved in study supervision, and critically revised the manuscript for important intellectual content. All authors have reviewed and commented on the final version of the manuscript submitted for publication.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

ETHICAL APPROVAL

The lead author affirms that the study has been conducted according to ethical legislation, was reviewed and approved by a medical ethics committee and performed according to the Declaration of Helsinki.

TRANSPARENCY DECLARATION

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

PEER REVIEW

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REFERENCES

1. Threapleton DE, Greenwood DC, Evans CE, Cleghorn CL, Nykjaer C, Woodhead C, et al. Dietary fibre intake and risk of cardiovascular disease: systematic review and meta-analysis. BMJ. 2013;347:f6879.
2. Bradbury KE, Appleby PN, Key TJ. Fruit, vegetable, and fiber intake in relation to cancer risk: findings from the European Prospective Investigation into Cancer and Nutrition (EPIC). Am J Clin Nutr. 2014;100:394S–8S.
3. Wannamethee SG, Whincup PH, Thomas MC, Sattar N. Associations between dietary fiber and inflammation, hepatic function, and risk of type 2 diabetes in older men: potential mechanisms for the benefits of fiber on diabetes risk. Diabetes Care. 2009;32:1823–5.
4. Liu S, Willett WC, Manson JE, Hu FB, Rosner B, Colditz G. Relation between changes in intakes of dietary fiber and grain products and changes in weight and development of obesity among middle-aged women. Am J Clin Nutr. 2003;78:920–7.
5. van de Vijver LP, van den Bosch LM, van den Brandt PA, Goldbohm RA. Whole-grain consumption, dietary fibre intake and body mass index in the Netherlands cohort study. Eur J Clin Nutr. 2009;63:31–8.
6. Zhang Z, Xu G, Liu D, Zhu W, Fan X, Liu X. Dietary fiber consumption and risk of stroke. Eur J Epidemiol. 2013;28:119–30.
7. Dukas L, Willett WC, Giovannucci EL. Association between physical activity, fiber intake, and other lifestyle variables and constipation in a study of women. Am J Gastroenterol. 2003;98:1790–6.
8. Anti M, Pignataro G, Armuzzi A, Valenti A, Iascone E, Marmo R, et al. Water supplementation enhances the effect of high-fiber diet on stool frequency and laxative consumption in adult patients with functional constipation. Hepatogastroenterology. 1998;45:727–32.
9. Marteau P, Jacobs H, Cazaubiel M, Signoret C, Prevel JM, Housez B. Effects of chicory inulin in constipated elderly people: a double-blind controlled trial. Int J Food Sci Nutr. 2011;62:164–70.
10. Micka A, Siepelmeyer A, Holz A, Theis S, Schön C. Effect of consumption of chicory inulin on bowel function in healthy subjects with constipation: a randomized, double-blind, placebo-controlled trial. Int J Food Sci Nutr. 2017;68:82–9.
11. McRorie JW, Daggy BP, Morel JG, Diersing PS, Miner PB, Robinson M. Psyllium is superior to docusate sodium for treatment of chronic constipation. Aliment Pharmacol Ther. 1998;12:491–7.
12. Weber TK, Toporovski MS, Tahan S, Neufeld CB, de Morais MB. Dietary fiber mixture in pediatric patients with controlled chronic constipation. J Pediatr Gastroenterol Nutr. 2014;58:297–302.
13. Wald A, Scarpignato C, Mueller-Lissner S, Kamm MA, Hinkel U, Helfrich I, et al. A multinational survey of prevalence and patterns of laxative use among adults with self-defined constipation. Aliment Pharmacol Ther. 2008;28:917–30.
14. Stewart WF, Liberman JN, Sandler RS, Woods MS, Stemhagen A, Chee E, et al. Epidemiology of constipation (EPOC) study in the United States: relation of clinical subtypes to sociodemographic features. Am J Gastroenterol. 1999;94:3530–40.
15. Zwiener R, Keller C, Robin S, Hyman PE, Palsson OS, Saps M, et al. Prevalence of Rome IV functional gastrointestinal disorders in children and adolescents in the United States. Gastroenterology. 2017;152:S649.
16. Gezondheidsraad. Richtlijn voor de vezelconsumptie. 2006;2006/03.
17. Stephen AM, Champ MM, Cloran SJ, Fleith M, van Lieshout L, Mejborn H, et al. Dietary fibre in Europe: current state of knowledge on definitions, sources, recommendations, intakes and relationships to health. Nutr Res Rev. 2017;30:149–90.
18. Cust AE, Skilton MR, van Bakel MM, Halkjaer J, Olsen A, Agnoli C, et al. Total dietary carbohydrate, sugar, starch and fibre intakes in the European Prospective Investigation into Cancer and Nutrition. Eur J Clin Nutr. 2009;63:S37–60.
19. van Rossum CT, Fransen HP, Verkaik-Kloosterman J, Buurma-Rethans EJM & Ocké MC Dutch National Food Consumption Survey

2007-2010: diet of children and adults aged 7 to 69 years. 2011. https://rivm.openrepository.com/handle/10029/261553
20. Giacco R, Costabile G, Della Pepa G, Anniballi G, Griffo E, Mangione A, et al. A whole-grain cereal-based diet lowers postprandial plasma insulin and triglyceride levels in individuals with metabolic syndrome. Nutr Metab Cardiovasc Dis. 2014;24:837–44.
21. Ellis J, Johnson MA, Fischer JG, Hargrove JL. Nutrition and health education intervention for whole grain foods in the Georgia Older Americans Nutrition Program. J Nutr Elderly. 2005;24:67–83.
22. Kellar I, Abraham C. Randomized controlled trial of a brief research-based intervention promoting fruit and vegetable consumption. Br J Health Psychol. 2005;10:543–58.
23. Ha E-J, Caine-Bish N. Effect of nutrition intervention using a general nutrition course for promoting fruit and vegetable consumption among college students. J Nutr Educ Behav. 2009;41:103–9.
24. Nour-Eldein H, Salama HM, Abdulmajeed AA, Heissam KS. The effect of lifestyle modification on severity of constipation and quality of life of elders in nursing homes at Ismailia city, Egypt. J Family Community Med. 2014;21:100–6.
25. Salmean YA, Zello GA, Dahl WJ. Foods with added fiber improve stool frequency in individuals with chronic kidney disease with no impact on appetite or overall quality of life. BMC Res Notes. 2013;6:510.
26. Meijboom S, van Houts-Streppel MT, Perenboom C, Siebelink E, van de Wiel AM, Geelen A, et al. Evaluation of dietary intake assessed by the Dutch self-administered web-based dietary 24-h recall tool (Compl-eat™) against interviewer-administered telephone-based 24-h recalls. J Nutr Sci. 2017;6:49.
27. Willett W. Nutritional epidemiology. New York: Oxford University Press; 2012.
28. Thompson FE, Subar AF. Dietary assessment methodology. In: Collins C, Kirkpatrick S. Editors. Nutrition in the prevention and treatment of disease. Elsevier, Amsterdam; 2017. p. 5–48.
29. Walton J. Dietary assessment methodology for nutritional assessment. Top Clin Nutr. 2015;30:33–46.
30. Lazarou C, Panagiotakos DB, Spanoudis G, Matalas AL. E-KINDEX: a dietary screening tool to assess children's obesogenic dietary habits. J Am Coll Nutr. 2011;30:100–12.
31. Bailey RL, Miller PE, Mitchell DC, Hartman TJ, Lawrence FR, Sempos CT, et al. Dietary screening tool identifies nutritional risk in older adults. Am J Clin Nutr. 2009;90:177–83.
32. Heller RF, Pedoe HDT, Rose G. A simple method of assessing the effect of dietary advice to reduce plasma cholesterol. Prev Med. 1981; 10:364–70.
33. Ammerman AS, Haines PS, DeVellis RF, Strogatz DS, Keyserling TC, Simpson RJ Jr, et al. A brief dietary assessment to guide cholesterol reduction in low-income individuals: design and validation. J Am Diet Assoc. 1991;91:1385–90.
34. Block G, Gillespie C, Rosenbaum EH, Jenson C. A rapid food screener to assess fat and fruit and vegetable intake. Am J Prev Med. 2000;18:284–8.
35. Bogers RP, van Assema P, Kester AD, Westerterp KR, Dagnelie PC. Reproducibility, validity, and responsiveness to change of a short questionnaire for measuring fruit and vegetable intake. Am J Epidemiol. 2004;159:900–9.
36. Van Assema P, Brug J, Ronda G, Steenhuis I, Oenema A. A short Dutch questionnaire to measure fruit and vegetable intake: relative validity among adults and adolescents. Nutr Health. 2002;16:85–106.
37. Rifas-Shiman SL, Willett WC, Lobb R, Kotch J, Dart C, Gillman MW. PrimeScreen, a brief dietary screening tool: reproducibility and comparability with both a longer food frequency questionnaire and biomarkers. Public Health Nutr. 2001;4:249–54.
38. Markland AD, Palsson O, Goode PS, Burgio KL, Busby-Whitehead J, Whitehead WE. Association of low dietary intake of fiber and liquids with constipation: evidence from the National Health and Nutrition Examination Survey (NHANES). Am J Gastroenterol. 2013;108:796–803.
39. Rijnaarts I, De Roos NM, Wang T, Zoetendal EG, Top J, Timmer M, et al. Increasing dietary fibre intake in healthy adults using personalised dietary advice compared with general advice: a single-blind randomised controlled trial. Public Health Nutr. 2020;24:1–12.
40. (2019/6.0) NEVO-online versie. Bilthoven: RIVM.
41. Streppel MT, de Vries JH, Meijboom S, Beekman M, de Craen AJ, Slagboom PE, et al. Relative validity of the food frequency questionnaire used to assess dietary intake in the Leiden Longevity Study. Nutr J. 2013;12:75.
42. Siebelink E, Geelen A, de Vries JH. Self-reported energy intake by FFQ compared with actual energy intake to maintain body weight in 516 adults. Br J Nutr. 2011;106:274–81.
43. Heaton K, Lewis S. Bristol stool chart. Scand J Gastroenterol. 1997;32: 920–4.
44. Bland JM, Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet. 1986;327:307–10.
45. Streppel MT, de Vries JH, Meijboom S, Beekman M, de Craen AJ, Slagboom PE, et al. Relative validity of the food frequency questionnaire used to assess dietary intake in the Leiden Longevity Study. Nutr J. 2013;12:1–8.
46. Kristal AR, Andrilla CH, Koepsell TD, Diehr PH, Cheadle A. Dietary assessment instruments are susceptible to intervention-associated response set bias. J Am Diet Assoc. 1998;98:40–3.
47. Baranowski T, Allen DD, Mâsse LC, Wilson M. Does participation in an intervention affect responses on self-report questionnaires? Health Educ Res. 2006;21:i98–109.
48. Thompson FE, Dixit-Joshi S, Potischman N, Dodd KW, Kirkpatrick SI, Kushi LH, et al. Comparison of interviewer-administered and automated self-administered 24-hour dietary recalls in 3 diverse integrated health systems. Am J Epidemiol. 2015;181: 970–8.
49. Naska A, Lagiou A, Lagiou P. Dietary assessment methods in epidemiological research: current state of the art and future prospects. F1000Res. 2017;6:926.
50. Aubertin-Leheudre M, Koskela A, Samaletdin A, Adlercreutz H. Responsiveness of urinary and plasma alkylresorcinol metabolites to rye intake in finnish women. Cancers. 2010;2:513–22.
51. Aubertin-Leheudre M, Koskela A, Samaletdin A, Adlercreutz H. Plasma alkylresorcinol metabolites as potential biomarkers of whole-grain wheat and rye cereal fibre intakes in women. Br J Nutr. 2010; 103:339–43.
52. Linko A-M, Juntunen KS, Mykkänen HM, Adlercreutz H. Whole-grain rye bread consumption by women correlates with plasma alkylresorcinols and increases their concentration compared with low-fiber wheat bread. J Nutr. 2005;135:580–3.
53. Andersson A, Marklund M, Diana M, Landberg R. Plasma alkylresorcinol concentrations correlate with whole grain wheat and rye intake and show moderate reproducibility over a 2- to 3-month period in free-living Swedish adults. J Nutr. 2011;141:1712–8.
54. Serra-Majem L, Frost Andersen L, Henríque-Sánchez P, Doreste-Alonso J, Sánchez-Villegas A, Ortiz-Andrelluchi A, et al. Evaluating the quality of dietary intake validation studies. Br J Nutr. 2009;102:S3–9.
55. Hernández T, Wilder L, Kuehn D, Rubotzky K, Moser-Veillon P, Godwin S, et al. Portion size estimation and expectation of accuracy. J Food Comp Anal. 2006;19:S14–21.
56. Lucassen DA, Willemsen RF, Geelen A, Brouwer-Brolsma EM, Feskens E. The accuracy of portion size estimation using food images and textual descriptions of portion sizes: an evaluation study. J Hum Nutr Diet. 2021. https://doi.org/10.1111/jhn.12878
57. Amoutzopoulos B, Page P, Roberts C, Roe M, Cade J, Steer T, et al. Portion size estimation in dietary assessment: a systematic review of existing tools, their strengths and limitations. Nutr Res. 2020;78:885–900.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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NUTRITIONAL ASSESSMENT

The accuracy of portion size estimation using food images and textual descriptions of portion sizes: an evaluation study

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Abstract

Background: Inaccurate self-report of portion sizes is a major cause of measurement error in dietary assessment. To reduce this error, different portion size estimation aids (PSEAs) have been developed, including food images (image based, IB-PSE) and textual descriptions of portion sizes (text-based, TB-PSE). We assessed the accuracy of portion size estimation by IB-PSE and TB-PSE.

Methods: True intake of one lunch was ascertained in forty participants. Self-reported portion sizes were assessed after 2 and 24 hours by means of TB-PSE and IB-PSE, in random order. Wilcoxon's tests were used to compare mean true intakes to reported intakes. Moreover, proportions of reported portion sizes within 10% and 25% of true intake were assessed. An adapted Bland-Altman approach was used to assess agreement between true and reported portion sizes. Analyses were conducted for all foods and drinks combined and for predetermined food types.

Results: No significant differences were observed between reported portion sizes at 2 and 24 hours after lunch. Combining median relative errors of all foods items resulted in an overall 0% error rate for TB-PSE and 6% error rate for IB-PSE. Comparing reported portion sizes within 10% (31% vs. 13%) and 25% (50% vs. 35%) of the true intake showed a better performance for TB-PSE compared to IP-PSE, respectively. Bland-Altman plots indicated a higher agreement between reported and true intake for TB-PSE compared to IB-PSE.

Conclusions: Although the use of TB-PSE still results in measurement error, our results suggest a more accurate dietary intake assessment with TB-PSE than IB-PSE.

KEYWORDS
Dietary assessment, Food images, Household measures, Portion size estimation, PSEA, Standard portion sizes

INTRODUCTION

Accurate dietary assessment is essential in nutrition research. Although dietary intake is still often assessed using paper-pencil tools, i.e. food frequency questionnaires (FFQs), food records (FRs) and 24-hour recalls (24hRs), dietary assessment techniques have advanced rapidly in recent years. The last decade numerous valuable computer-based

and web-based tools, mostly based on 24hRs and FFQs, have been developed.[1-3] More recently also different smartphone applications (i.e. apps), mostly based on FRs, have been developed to collect real-time dietary intake data.[3,4] Important benefits of these new tools include that they are assumed to lower burden on both participant and researcher compared to traditional techniques.[3-6]

A fundamental aspect of accurate dietary assessment is portion size estimation.[6-8] However, assessment of portion sizes is challenging and a major cause of error in dietary assessment.[6,9-11] Difficulties occur while reporting previously consumed foods as well as when judging displayed foods.[4,11,12] The accuracy of portion size estimation is affected by various factors, including type of food and serving size.[6,10,13] Generally, single-unit foods (e.g. sliced bread, fruits) are more likely to be reported correctly compared to liquids or amorphous foods (e.g. pasta, lettuce).[4,12,14] Another issue in portion size estimation is that large portions tend to be underestimated and small portions tend to be overestimated, which is also known as the 'flat-slope phenomenon'.[11] In addition, foods consumed in small portions (e.g. spreads) are likely to be estimated more accurately than large portions of foods.[13]

Portion size estimation aids (PSEAs) (e.g. images, referent objects, portion size suggestions) have been suggested to result in more accurate portion sizes estimates.[15-17] However, research indicates that these PSEAs still result in measurement error and that further optimization of PSEAs is needed [17], especially with respect to PSEAs that may be implemented in web-based and smartphone-based dietary assessment tools. The most commonly used PSEAs in web-based and smartphone-based tools are portion size suggestions (i.e. standard portion sizes and household measures), food images, and free entry of weight in grams.[1] As individuals fail to recognize the metric quantities of portion sizes, estimations in grams are usually inaccurate.[18] For this reason, participants tend to prefer the use of household measures rather than estimation in grams.[17,18] Yet, inconsistent or vague descriptions of household measures may still result in measurement error, especially among individuals that are not frequently involved in meal preparation.[18,19] Therefore, clear descriptions of the portion sizes are crucial.[20]

To facilitate the estimation of portion sizes, several dietary assessment tools have included food images as visual aids, where individuals are requested to select the most comparable image with respect to the portion size consumed or displayed (i.e. image-based portion size assessment or IB-PSE). Previous research indicates that IB-PSE is particularly influenced by three main elements, namely perception, conceptualization and memory.[13] Despite these elements of potential error, IB-PSE is suggested to be a useful aid to estimate portion sizes.[14,21-24] However, there is only limited evidence on the reliability of IB-PSE in real-life situations.[14,19] Up to now, the reliability of IB-PSE has mainly been examined by exposing participants to foods and food images simultaneously while focussing on perception and not conceptualization and memory.[22-24] More specifically, the majority of previous research only compared PSEAs to weighed portion sizes as a reference technique.[12,19,21-24] To the best of our knowledge, none of the previous studies examined the accuracy of portion size estimation using a combination of textual descriptions of household measures (e.g. spoons, cups, glasses), standard portion sizes (e.g. small, medium, large) and estimation in grams (i.e. for the purpose of this study referred to as text-based portion size estimation or TB-PSE) and IB-PSE.

Therefore, the current study aimed to compare the accuracy of TB-PSE and IB-PSE. As we hypothesize that accuracy varies over different food types, accuracy of both PSEAs was examined for all foods and drinks combined and for specific food types. In addition, to gain a first insight in the effect of memory on the accuracy of the PSEAs, the portion sizes were reported after either 2 hours or 24 hours.

MATERIALS AND METHODS

Participants

Participants were recruited through a convenience sampling method using a database of research volunteers of the division of Human Nutrition and Health of Wageningen University and Research (WUR), social media accounts of the division (i.e. Facebook and Twitter), and through posters. Eligible participants were Dutch speaking, not visually impaired, not participating in another dietary intervention study, not an employee of the division, and not having any formal training in the field of nutrition. In total, 40 participants aged 20-70 years old were included in this study that was conducted during a 2-week period in February 2018. Participants were stratified by sex and age to ensure equal distribution of these characteristics and randomly assigned to two groups. Participants were informed that the study focused on different digital methods to assess food intake. The true study purpose was not disclosed until the end of the study. Written informed consent was obtained from all participants.

Overall study design

Participants were invited for one lunch at the study centre as part of the cross-over study and asked to complete two dietary questionnaires on a tablet or computer; 2 and 24 hours after lunch. The first group reported their food intake 2 hours after lunch by means of TB-PSE and 24 hours after lunch by means of IB-PSE. The second group reported their intake with the two PSEAs in the opposite order. As previous studies suggest that the potential difficulty to accurately estimate portion size depends on the type of food, we offered a variety of commonly consumed food types in the Netherlands [7,12-14] (Table 1). Each participant was provided with pre-weighed, ad libitum amounts of the food items.

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TABLE 1 Food items offered, by food type.

Offered food items
Amorphous
- Cheese
- Crunchy muesli
- Fruit salad
- Scrambled eggs
- Yogurt
Liquids
- Milk
- Orange juice
- Water
Single-units
- Bread slices
- Bread rolls
Spreads
- Jam
- Margarine

Each item was offered in a container without indication of the content. To minimize the effect of tableware on portion size estimation [25], the participants received a variety of tableware. After lunch, plate waste was weighed to assess true intake of each food item. Weights were taken with 'Sartorius Signum 1' calibrated weighing scales. True intake was calculated by the following formula:

$$\text{True intake (g)} = \text{Pre - weighed food item (g)} - \text{Plate waste food item (g)}$$

Portion size assessment

For the purpose of this study, a TB-PSE and IB-PSE questionnaire was developed in Qualtrics (Qualtrics, Provo, UT, USA). The question formulation and portion size estimation within the TB-PSE questionnaire were based on Compl-eat™; a self-administered web-based dietary 24hR-tool developed by WUR [20]. Portion sizes described in Compl-eat™ are a combination of estimation in grams/millilitres, standard portion sizes and household measures, which are based on the 'Food portion sizes and coding instructions'.[26] The question formulation within the IB-PSE questionnaire was also based on Compl-eat™, thus ensuring that observed differences were solely due to the different PSEAs and not due to differences in question formulation. For the IB-PSE questionnaire, the portion size images from the Automated Self-Administered 24-hour dietary recall (ASA24) picture book, developed by the National Cancer Institute, Bethesda, MD [27], were used. This picture book contains 3 to 8 portion size images per food item. To the best of our knowledge, this is the only freely available picture book portraying food images with known amounts (g) for research purposes.[28] Questionnaires started with questions whether or not a type of food was consumed, which was followed by questions on the amount of food consumed by means of one of the PSEAs. An example question from each questionnaire can be found in Supplement S1.

Additional measurements

On the study day, participants completed a short questionnaire about basic characteristics (i.e. age, sex, educational level). In addition, weight and height were measured to calculate participants' BMI (kg/m^2). Participants were characterized in three educational levels (low: primary or lower education, intermediate: secondary or higher vocational education, high: college or university) and four age groups (18-28, 29-45, 46-55, 56-70 years).

Statistical analysis

Normally distributed data is displayed as means (M) and standard deviations (SDs) in case of continuous variables, or frequencies in case of categorical variables; non-normally distributed data as medians and interquartile ranges (IQRs). Significant differences between true and reported intake, and between 2 and 24 hours, were assessed for each PSEA. To allow comparison between PSEAs across different food types, relative differences were calculated. As previous research indicated that accuracy of portion size estimation varies over food types, all analyses were conducted for all foods and drinks combined and for predetermined food types individually (i.e. "all foods excluding liquids", "amorphous foods", "liquids", "single-units", "spreads"; Table 1). As there are no guidelines on the acceptable level of accuracy [7,14,29], the proportion of the reported intake that fell within 10% and 25% of true intake were assessed, which is in line with comparable studies in this research area.[14] Proportions within 10% of true intake will be deemed acceptably accurate, whereas proportions within 25% of true intake will be used to get further insight in the levels of accuracy.[30] To determine agreement between reported and true intake for both PSEAs, Bland-Altman plots with 95% limits of agreement (LOA) were plotted. Usually the Bland-Altman method is applied for assessing agreement between two imperfect measures. Since true intake was assessed an adapted Bland-Altman method was used to plot the differences between reported and true intake against true intake.[14,31] However, when true intake increased, the absolute error increased. Therefore, we plotted the log-transformed ratio of reported and true intake against log-transformed true intake. Middle line indicates the mean and the upper and lower lines indicate borders based on mean ±1.96 SD. Since the variables were not normally distributed, Wilcoxon signed rank test was used to test within group and the Wilcoxon rank sum test was used to test for between group differences. All analyses were conducted with SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). Statistical significance was set at $p < 0.05$.

RESULTS

A total of 40 participants took part in this study. Participants had a mean ±SD age of 46.9 ± 19.2 years (range

20.7-69.4 years), BMI 24.9 ± 3.8 kg/m^2, 47.5% was men and the majority of the population was highly educated (62.5%). Participant characteristics did not significantly differ between group 1 (2hR: TB; 24hR: IB) and group 2 (2hR: IB; 24hR: TB) (Table 2). Furthermore, no significant differences were observed between reported at 2 and at 24 hours after lunch, for each PSEA. Therefore, the results are only shown per PSEA and are not subdivided per time point.

Median true intake for "all foods and drinks combined" was 94 g (IQR: 128 g), while median reported intake was 75 g (IQR: 120 g) for TB-PSE and 88 g (IQR: 164 g) for IB-PSE. Comparing the true intake with the reported intake, as assessed with TB-PSE, pointed towards significant differences for "all foods excluding liquids", "amorphous foods", "liquids" and "spreads" (Table 3). For IB-PSE, significant differences with the true intake were observed for "all foods and drinks combined", "liquids", "single-units" and "spreads". For "all foods and drinks combined" the median relative difference was 0% (IQR: 44%) as assessed by TB-PSE, and 6% (IQR: 115%) as assessed by IB-PSE (Table 3).

Significantly higher relative errors were shown for IB-PSE than for TB-PSE for "all foods and drinks combined", "all foods excluding liquids", "amorphous foods" and "liquids". For "all foods and drinks combined" the proportion of reported intakes within 10% of true intake was 31% for TB-PSE and 13% for IB-PSE, the proportion within 25% of true intake was 50% for TB-PSE and 35% for IB-PSE. For TB-PSE, the lowest proportion within 10% and 25% of true intake was observed for "spreads", whereas for IB-PSE, the lowest proportion was observed for "liquids". The highest proportion of reported intake that fell within 10% and 25% of true intake was, for both PSEAs, observed for the food type "single-units" (Table 3).

The log-transformed Bland-Altman plot of "all foods and drinks combined" showed a higher level of agreement for TB-PSE (M: 0.04; LOA: −1.11-1.03) than for IB-PSE, as shown by more widely scattered estimates and wider limits of agreement for IB-PSE (Supplement S2). Excluding liquids did not substantially alter these findings; agreement for TB-PSE (M: −0.10; LOA: −1.22-1.00) remained higher compared to IB-PSE (M:0.03; LOA: −1.37-1.43). The same trend was observed for the other food types (Supplement S2). The highest level of agreement was observed for "single-units" (TB-PSE M: −0.02; LOA: −0.30-0.25 vs. IB-PSE M: −0.09; LOA: −0.84-0.66), whereas the lowest level of agreement was observed for "amorphous foods" (TB-PSE M: −0.13; LOA: −1.43-1.15 vs. IB-PSE M: 0.17; LOA: −1.38-1.71).

DISCUSSION

In this study, the reported intake and its estimation error for "all foods and drinks combined" using IB-PSE significantly differed from true intake while no statistically significant difference was observed between the reported intake and its estimation error from true intake using TB-PSE. However, as indicated by the proportion of reported intakes within 10% and 25% of true intake, being 31% and 50% using TB-PSE compared to 13% and 35% using IB-PSE, meaning that for both PSEA's only the minority of estimations lies within the acceptable range, further improvements to increase the accuracy of portion size estimation are needed.

Before discussing our findings, the strengths and limitations of our study will be discussed. First, despite the fact that participants consumed their lunch in a controlled setting, we strived to mimic a real-life situation. Specifically, in contrast to most other studies, participants could choose from a selection of food items and actually consumed the selected items.[19,24] Furthermore, participants had the opportunity to choose between different sizes of tableware [25] and had ad libitum access to the foods provided.[32] Moreover, all products were served in bowls, jugs and plates without indication of content. Second, as the accuracy of two PSEAs was assessed separately, accuracy of both methods could be studied independently. Moreover, due to the study's cross-over design the accuracy of both PSEAs was assessed in each participant. Third, to our knowledge, this is the first study comparing the two PSEAs, while keeping all other factors in the questionnaire identical. Finally, to avoid extra focus on portion sizes, participants were not informed on the goal of the study

TABLE 2 Characteristics of the participants.

	Total (n = 40)			Group 1[†] (n = 20)			Group 2[‡] (n = 20)		
	Mean	SD	%	Mean	SD	%	Mean	SD	%
Men			47.5			50.0			45.0
Age (years)	46.9	19.2		48.7	19.8		45.0	18.9	
BMI (kg/m^2)	24.9	3.8		25.9	4.1		24.0	3.3	
Educational level									
Low			0.0			0.0			0.0
Intermediate			37.5			35.0			40.0
High			62.5			65.0			60.0

Note: No significant differences were found between groups.

[†]Group 1: 2hR = TB-PSE; 24hR = IB-PSE

[‡]Group 2: 2hR = IB-PSE; 24hR = TB-PSE

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TABLE 3 Median true intake, median reported intake for both PSEAs, and reported intakes within 10% and 25% of true intake for both PSEAs for all foods and per food type.

	Obs (n)	Median true intake (g, IQR)	TB-PSE					IB-PSE				
			Median rep. intake (g, IQR)	Median diff. (g, IQR)†	Median rel. diff. (%, IQR)‡	<10% of true (%)	<25% of true (%)	Median rep. intake (g, IQR)	Median diff. (g, IQR)†	Median rel. diff. (%, IQR)‡	<10% of true (%)	<25% of true (%)
All food items	326	94 (128)	75 (120)	0 (25)	0 (44)	31	50	88 (164)	3 (74)***	6 (115)***	13	35
All excl. liquids	263	66 (86)	50 (101)	0 (22)***	0 (44)	32	49	61 (95)	−1 (41)	−5 (74)**	15	41
Amorphous	150	84 (124)	66 (107)	−7 (45)**	−12 (56)	12	25	104 (119)	3 (70)	4 (109)***	13	31
Liquids	63	194 (125)	220 (150)	29 (80)***	15 (39)	30	56	355 (356)	211 (373)***	118 (122)***	5	11
Single-units	59	100 (50)	100 (50)	0 (0)	0 (0)	95	95	72 (61)	−7 (25)*	−14 (18)	29	80
Spreads	54	17 (15)	15 (14)	−3 (14)*	−23 (63)	9	24	14 (12)	−3 (10)*	−22 (63)	9	30

Note: All food items., all foods and drinks combined; obs., observations; rep., reported; diff., difference; rel., relative; excl., excluding.

†Calculated as reported intake minus true intake. Thus, positive differences represent overestimations and negative differences represent underestimations. Significant differences between reported and true intake was assessed with a Wilcoxon signed-rank test. Significant differences are indicated by * for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.0001$.

‡Relative differences (%) = (reported intake (g) −true intake (g)) / true intake (g) * 100. Significant differences between intake reported with TB-PSE and IB-PSE were assessed with a Wilcoxon signed-rank test. Significant differences are indicated by * for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.0001$ in the IB-PSE "Mean rel. diff. column".

and did not see the weighing of the foods. A limitation of our study is that we used the ASA24 picture book in a Dutch population. The ASA24 is the only freely available photo database for research with known portion size weights. However, the ASA24 photographs are based on the 5th and 95th percentile of intake per product in the US and as such tailored for usage in the US.[14,33,34] It is known that portion sizes in the US are larger than in the Netherlands.[35,36] To illustrate, the glasses in the study of Donders-Engelen *et al.* [26] range between 100 g and 220 g whereas the glasses in ASA24 range between 177 g and 473 g. As ASA24 does not contain pictures of the smallest portion sizes consumed in the Netherlands, this may explain the overestimated intakes by IB-PSE estimates in our study (e.g. 118% for "liquids"). However, we have to note that the portion size database that currently is being used in the Netherlands dates from 2003. It is known that plate sizes have increased in the past decades [36], which on its turn may have led to an underestimation of TB-PSEs.

A more general limitation of the ASA24 food images is the usage of cutlery as reference, which is meant to help participants estimate the real-life size of a portion. However, as cutlery can vary in size, it might not be the best reference and as such explain the more scattered points observed in the Bland-Altman plot of IB-PSE compared to TB-PSE. Finally, in view of generalisability it needs to be mentioned that our participants were relatively old and highly educated. However, several previous studies concluded that age and education level did not affect the participants ability to estimate portion sizes.[19,22,23,37] In addition, we only tested a limited number of food items, and as such our findings are only applicable to these tested food items.

As hypothesized, the accuracy of reported intake with both PSEAs varied between the different food types. Both PSEAs overestimated the median reported intake of "liquids" whereas the intake of "all foods excluding liquids" and "spreads" were (slightly) underestimated. In addition, for TB-PSE, the reported median intake of "amorphous foods" was underestimated, while for IB-PSE the intake was overestimated. Previous research showed both under- and overestimations of portion size estimations.[7,14] Moreover, the accuracy of food intake estimates varied depending on the food types.[12,13,38] Both PSEAs showed the highest estimation errors for "liquids, which is not in line with similar studies showing the highest estimation errors for "amorphous foods".[12-14,37] In contrast to previous studies, which mostly provided liquids in containers that were identical to containers portrayed on the images, we aimed to resemble the real-life situation and therefore studied commonly-used PSEA descriptions and used glasses that did not necessarily match with the glasses on the images. As conceptualization plays a major role in the accurateness of portion size estimation[13], it is easier to estimate portion sizes when the portion sizes are similar to the portions portrayed on the images[23,39] or the textual descriptions.[18,20] For instance, the description "lemonade glass" lacks detail and can easily result in misclassification. In agreement with our study, Hernandez *et al.* [7] also studied the intake of liquids in containers that were not

identical to the containers on the images and also observed the highest estimation errors for liquids, which underlines the influence of conceptualization.

As illustrated by small errors for "single-units" and "spreads" and larg(er) errors for "amorphous foods" and "liquids" for both PSEAs, our findings clearly indicate that foods consumed in small or defined units are more accurately estimated than foods consumed in larger amounts. These findings are in line with previous studies.[23,37,39] Generally, the accuracy for the food types "amorphous foods", "liquids" and "single-units" was higher for TB-PSE than for IB-PSE estimates, except for "spreads" which were more accurately estimated with IB-PSE. The latter may relate to the fact that textual description of the size of spoons and spread on bread is open to interpretation, whereas a picture may provide a better impression of the portion size estimate.[13] Moreover, the fact that we used images of spoons, instead of images of spread on bread, to estimate the amount of "spreads" consumed, may have resulted in more accurate estimates for this food type.[12] The size of the bread might influence the perception of the portion size and thereby lead to errors in estimations.[21]

We found no significant differences in accuracy between reporting after 2 hours and 24 hours for each of the PSEAs. Based on this, we concluded that memory did not influence the accuracy of portion size estimations within this timeframe. Therefore, only the combined results per PSEA were used for further analysis. However, after dividing the participants per PSEA over the two time points, the sample size per group was very small (i.e. ~20 participants) and therefore we had less power to detect significant differences. Previous research has shown that errors increase after 1-2 hours, compared to immediate estimations.[24] However, our first time point was after two hours and in line with our results, De Keyzer *et al.* [21] found no increase in estimation errors after 1-2 days compared to after 4 days.[21] To truly understand the effect of memory on accuracy of portion size estimation more research is needed with a larger sample size.

Due to lack of consensus on the minimal required level of accuracy for PSEAs no strong conclusion can be drawn on that matter. However, the accuracy of the reported intake by TB-PSE was higher than by IB-PSE for all food types except for "spreads", which was higher with IB-PSE. Overall, TB-PSE provided more accurate portion size estimations than IB-PSE. As discussed, these findings are different from previous studies.[14,21-24] However, in contrast to these studies we incorporated all elements that influence IB-PSE (i.e. perception, conceptualization, memory), instead of focusing on one or two of these elements [22-24], in an attempt to mimic a real-life situation. Therefore, our findings in combination with previous studies may indicate that IB-PSE is a useful PSEA, but only when judging displayed foods and not for retrospective portion size estimation.

TB-PSE and IB-PSE were selected due to their applicability for implementation in web-based and smartphone-base dietary assessment tools. However, there are other PSEAs which would be applicable for implementation in web-based or smartphone-based dietary assessment tools (e.g. remote food photography method, body-worn monitors).[8,40] These innovative tools also have a range of drawbacks, for instance, it is known that they are unable to detect all aspects of the food consumed (e.g. no difference detected between spinach vs. spinach a la crème).[41] Furthermore, individuals might feel uncomfortable wearing the device, especially long-term, and it is difficult to guarantee the privacy of bystanders.[40] Moreover, even though these devices have been proven to be up to 90% accurate[40], such devices are expensive and therefore not suited for large-scale studies. Selecting a PSE-tool needs to be considered carefully while taking into account study design, methods and target group.[8] Therefore, even though there are new, more innovative PSE-tools being developed, it is still valuable to further improve both TB-PSE and IB-PSE. These PSEAs are easy to implement in web-based and smartphone-based tools, relatively inexpensive, well-known and therefore easy to use with limited training.

To conclude, in our study TB-PSE is shown to be more accurate than IB-PSE. Country-specific pictures with a clear reference are needed to improve the accuracy of IB-PSE. Next to this, we can conclude that TB-PSE seems to be an accurate PSEA for "single-units", as 95% of the reported intake fell within 10% of true intake. However, for the other food types, only 32% or less of the reported intakes fell within 10% of truth. Therefore, in line with Bucher *et al.* [42], we conclude that the accuracy of portion size estimations with TB-PSE needs to be improved further and therefore standardized terminology is needed to avoid ambiguity with regard to textual descriptions of portion sizes. Finally, the use of a combination of PSEAs might be valuable to increase accuracy of portion size estimation.

ETHICS STATEMENT

According to the Central Committee on Research involving Human Subjects (CCMO), this type of study did not require approval from an ethics committee in the Netherlands.

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CONFLICT OF INTEREST

The authors had no financial or personal conflicts of interest to declare.

AUTHOR CONTRIBUTION

The authors contributions are as follows: D.A.L. contributed to the study design, data collection, interpretations of the findings, data analysis and drafted the manuscript; R.F.W.

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contributed to the study design, data collection, data analysis, interpretation of the findings and revised earlier versions of the manuscript; A.G. contributed to the study design, interpretations of the findings and revised earlier versions of the manuscript; E.B.B. and E.J.M.F. contributed to the interpretations of the findings and revised earlier versions of the manuscript. All authors read and approved the final version of the manuscript.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The reporting of this work is compliant with STROBE guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained. The study has not been registered in any trials registry.

PEER REVIEW

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REFERENCES

1. Timon CM, van den Barg R, Blain RJ, Kehoe L, Evans K, Walton J, et al. A review of the design and validation of web- and computer-based 24-h dietary recall tools. Nutr Res Rev. 2016;29:268–80.
2. Ngo J, Engelen A, Molag M, Roesle J, García-Segovia P, Serra-Majem L, et al. A review of the use of information and communication technologies for dietary assessment. Br J Nutr. 2009;101(Suppl 2):S102–112.
3. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiol Health. 2014;36:e2014009.
4. Thompson FE, Subar AF. Dietary Assessment Methodology. In Nutrition in the Prevention and Treatment of Disease. Elsevier Inc.; 2017. p. 5–48.
5. Naska A, Lagiou A, Lagiou P. Dietary assessment methods in epidemiological research: current state of the art and future prospects. F1000Research. 2017;6:926.
6. Walton J. Dietary Assessment Methodology for Nutritional Assessment. Topics in Clinical Nutrition. 2015;30:33–46.
7. Hernández T, Wilder L, Kuehn D, Rubotzky K, Moser-Veillon P, Godwin S, et al. Portion size estimation and expectation of accuracy. J Food Compost Anal. 2006;19:S14–S21.
8. Sharma V, Chadha R. Effectiveness of food portion size estimation aids for diet assessment: a systematic review. Int J Food Sci Nutr. 2017;2:106–12.
9. Subar AF, Freedman LS, Tooze JA, Kirkpatrick SI, Boushey C, Neuhouser ML, et al. Addressing current criticism regarding the value of self-report dietary data. J Nutr. 2015;145:2639–45.
10. Vuckovic N, Ritenbaugh C, Taren DL, Tobar M, et al. A qualitative study of participants' experiences with dietary assessment. J Am Diet Assoc. 2000;100:1023–8.
11. Young LR, Nestle MS. Portion sizes in dietary assessment: issues and policy implications. Nutr Rev. 1995;53:149–58.
12. Subar AF, Crafts J, Zimmerman TP, Wilson M, Mittl B, Islam NG, et al. Assessment of the accuracy of portion size reports using computer-based food photographs aids in the development of an automated self-administered 24-hour recall. J Am Diet Assoc. 2010;110:55–64.
13. Nelson M, Atkinson M, Darbyshire S. Food photography. I: the perception of food portion size from photographs. Br J Nutr. 1994;72:649–63.
14. Kirkpatrick SI, Potischman N, Dodd KW, Douglass D, Zimmerman TP, Kahle LL, et al. The use of digital images in 24-hour recalls may lead to less misestimation of portion size compared with traditional interviewer-administered recalls. J Nutr. 2016;146:2567–73.
15. Byrd-Bredbenner C, Schwartz J. The effect of practical portion size measurement aids on the accuracy of portion size estimates made by young adults. J Hum Nutr Diet. 2004;17:351–7.
16. Faggiano F, Vineis P, Cravanzola D, Pisani P, Xompero G, Riboli E, et al. Validation of a method for the estimation of food portion size. Epidemiology. 1992;3:379–82.
17. Faulkner GP, Livingstone MBE, Pourshahidi LK, Spence M, Dean M, O'Brien S, et al. An evaluation of portion size estimation aids: precision, ease of use and likelihood of future use. Public Health Nutr. 2016;19:2377–87.
18. Spence M, Livingstone M, Hollywood LE, Gibney ER, O'Brien SA, Pourshahidi L, et al. A qualitative study of psychological, social and behavioral barriers to appropriate food portion size control. Int J Behav Nutr Phys Act. 2013;10:92.
19. Biltoft-Jensen A, Holmgaard Nielsen T, Hess Ygil K, Christensen T, Fagt S. Accuracy of food photographs for quantifying food servings in a lunch meal setting among Danish children and adults. J Hum Nutr Diet. 2018;31:131–40.
20. Meijboom S, van Houts-Streppel MT, Perenboom C, Siebelink E, van de Wiel AM, Geelen A, et al. Evaluation of dietary intake assessed by the Dutch self-administered web-based dietary 24-h recall tool (Compl-eat™) against interviewer-administered telephone-based 24-h recalls. J Nutr Sci. 2017;6:e49.
21. De Keyzer W, Huybrechts I, De Maeyer M, Ocké M, Slimani N, van 't Veer P, et al. Food photographs in nutritional surveillance: errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption. Br J Nutr. 2011;105:1073–83.
22. Naska A, Valanou E, Peppa E, Katsoulis M, Barbouni A, Trichopoulou A, et al. Evaluation of a digital food photography atlas used as portion size measurement aid in dietary surveys in Greece. Public Health Nutr. 2016;19:2369–76.
23. Ovaskainen M-L, Paturi M, Reinivuo H, Hannila M-L, Sinkko H, Lehtisalo J, et al. Accuracy in the estimation of food servings against the portions in food photographs. Eur J Clin Nutr. 2008;62:674–81.
24. Szenczi-Cseh J, Horvath Z, Ambrus A. Validation of a food quantification picture book and portion sizes estimation applying perception and memory methods. Int J Food Sci Nutr. 2017;68:960–72.
25. Van Ittersum K, Wansink B. Plate size and color suggestibility: the Delboeuf Illusion's bias on serving and eating behavior. J Consum Res. 2011;39:215–28.
26. Donders-Engelen MR, Van der Heijden LJM, Hulshof KFAM. (2003) Maten, Gewichten en Codenummers 2003. Food Portion Sizes and Coding Instructions. Division of Human Nutrition and TNO Nutrition.
27. Subar AF, Kirkpatrick SI, Mittl B, Zimmerman TP, Thompson FE, Bingley C, et al. The Automated Self-Administered 24-hour dietary recall (ASA24): a resource for researchers, clinicians, and educators from the National Cancer Institute. J Acad Nutr Diet. 2012;112:1134–7.
28. ASA24. ASA24: Automated Self-Administrated 24-hour dietary assessment tool; 2018. https://epi.grants.cancer.gov/asa24/respondent/citations.html (accessed 30-04-2018).
29. European Food Safety Authority. Use of the EFSA Comprehensive European Food Consumption Database in Exposure Assessment. EFSA Journal; 2011:9:2097.
30. Lombard MJ, Steyn NP, Charlton KE, Senekal M. Application and interpretation of multiple statistical tests to evaluate validity of dietary intake assessment methods. Nutr J. 2015;14:40.
31. Krouwer JS. Why Bland-Altman plots should use X, not (Y+ X)/2 when X is a reference method. Stat Med. 2008;27:778–80.
32. Clancy AK, Woods K, McMahon A, Probst Y. Food composition database format and structure: a user focused approach. PLoS One. 2015;10:e0142137.
33. Kirkpatrick SI, Subar AF, Douglass D, Zimmerman TP, Thompson FE, Kahle LL, et al. Performance of the Automated Self-Administered 24-hour Recall relative to a measure of true intakes

and to an interviewer-administered 24-h recall. Am J Clin Nutr. 2014;100:233–40.
34. Kirkpatrick SI, Thompson FE, Subar AF. Validity of the National Cancer Institute's Automated Self-Administered 24-hour Recall (ASA24): results of a feeding study. FASEB J. 2013;27:230.234.
35. Rozin P, Kabnick K, Pete E, Fischler C, Shields C. The ecology of eating: smaller portion sizes in France Than in the United States help explain the French paradox. Psychol Sci. 2003;14:450–4.
36. Steenhuis IH, Leeuwis FH, Vermeer WM. Small, medium, large or supersize: trends in food portion sizes in The Netherlands. Public Health Nutr. 2010;13:852–7.
37. Bucher T, Weltert M, Rollo ME, Smith SP, Jia W, Collins CE, et al. The international food unit: a new measurement aid that can improve portion size estimation. Int J Behav Nutr Phys Act. 2017;14:124.
38. Robson PJ, Livingstone MBE. An evaluation of food photographs as a tool for quantifying food and nutrient intakes. Public Health Nutr. 2000;3:183–92.
39. Vereecken CA, Covents M, Matthys C, Maes L, et al. Young adolescents' nutrition assessment on computer (YANA-C). Eur J Clin Nutr. 2005;59:658–67.
40. McClung HL, Ptomey LT, Shook RP, Aggarwal A, Gorczyca AM, Sazonov ES, et al. Dietary intake and physical activity assessment: current tools, techniques, and technologies for use in adult populations. Am J Prev Med. 2018;55:e93–e104.
41. Fengqing Zhu, Bosch M, Insoo Woo, SungYe Kim, Boushey CJ, Ebert DS, et al. The use of mobile devices in aiding dietary assessment and evaluation. IEEE J Sel Top Signal Process. 2010;4:756–66.
42. Bucher T, Rollo ME, Smith SP, Dean M, Brown H, Sun M, et al. Position paper on the need for portion-size education and a standardised unit of measurement. Health Promot J Austr. 2017;28:260–3.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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