ORIGINAL ARTICLE

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]

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

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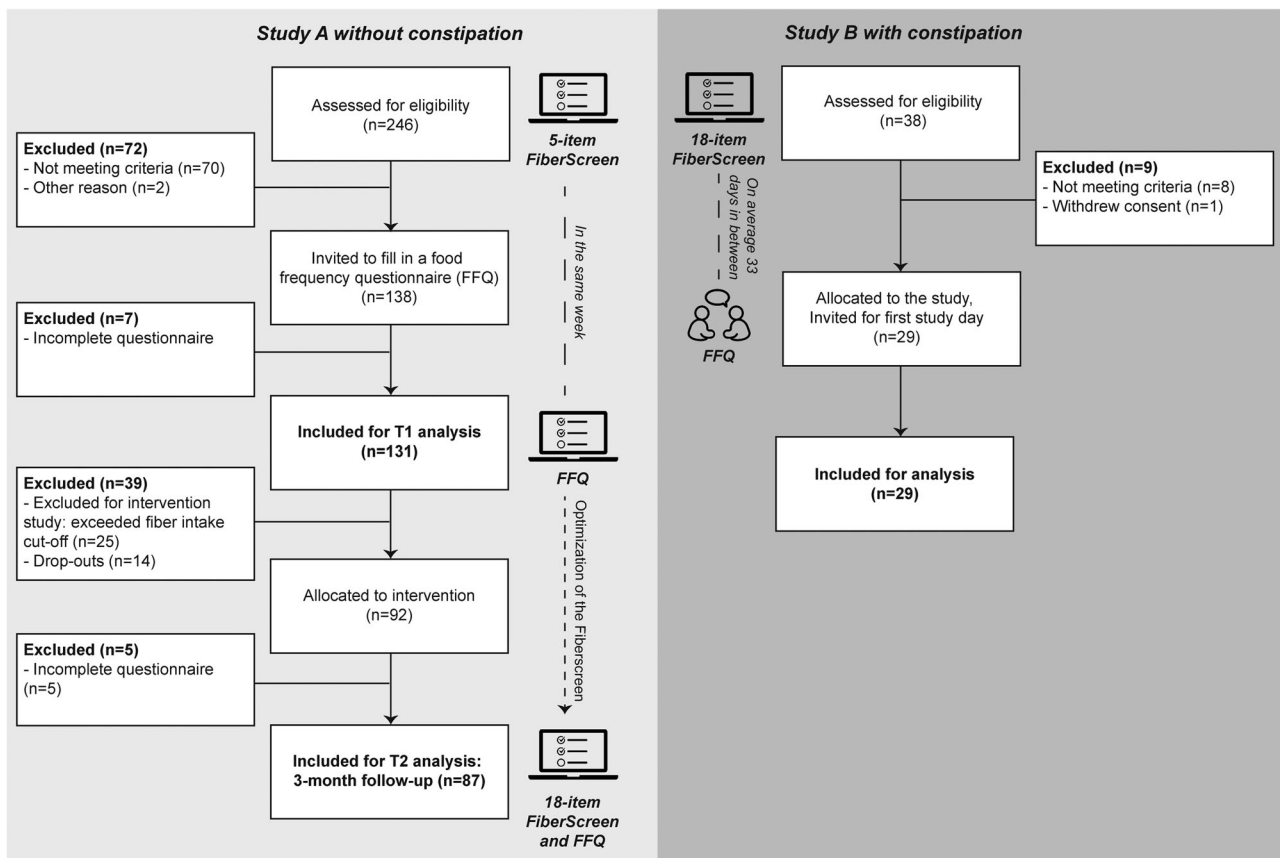
FIGURE 1 Design and participant flowchart of both Study A and B

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,

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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 ($\Delta = 1.22 \pm 5.9$ 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 ($ß_{males} = 0.07 ± 0.16$, $p = 0.660$; $ß_{females} = −0.06 ± 0.14$, $p = 0.680$) (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
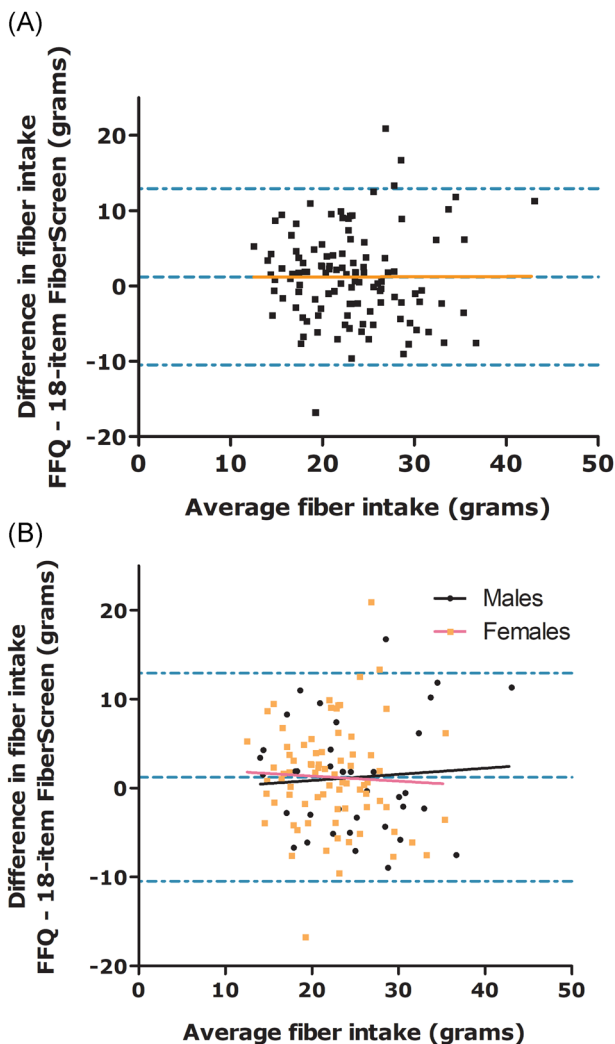
FIGURE 2 (a) Bland–Altman plot of fibre intake of both Study A and B. (b) Bland–Altman plot of fibre intake of both Study A and B, stratified for gender. Both plots show the difference of the fibre estimate between the food frequency questionnaire (FFQ): the 18-item FiberScreen on the y-axis versus the 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
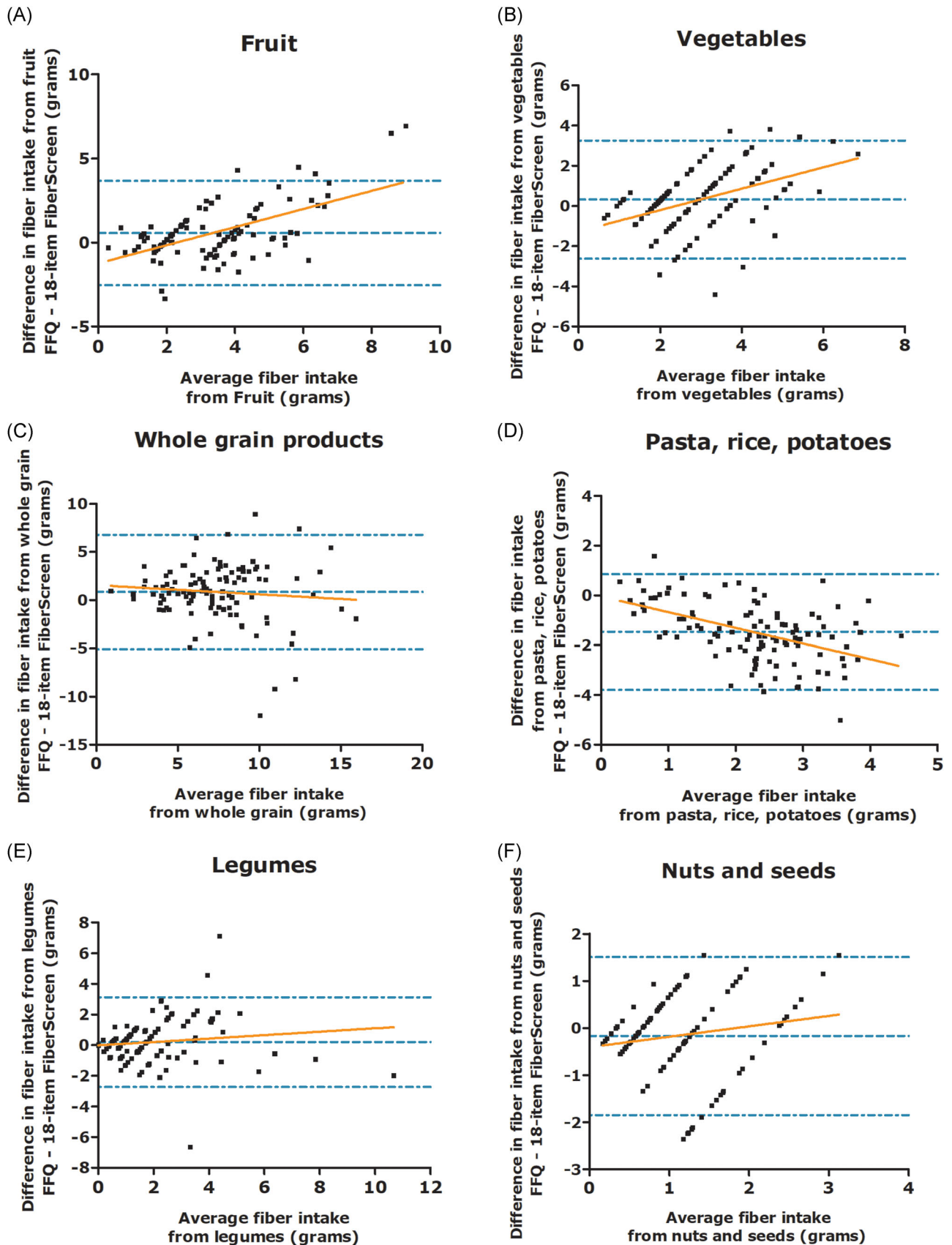
(A)

Fruit

(B)

Vegetables

(C)

Whole grain products

(D)

Pasta, rice, potatoes

(E)

Legumes

(F)

Nuts and seeds

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

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.

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