FRUGGIES FOR ALL

Evaluation of an integrated nutrition-sensitive project targeted to increase fruit and vegetable consumption in urban Vietnam and Nigeria

Giulia Pastori

PROPOSITIONS

1. Simple indicators improve awareness of the widespread existence of suboptimal diets.
   (this thesis)

2. Fruit and vegetable consumption can only be increased by simultaneously addressing accessibility, affordability, and acceptability.
   (this thesis)

3. Underlying assumptions, motivations and values of high-income countries researchers inevitably overshadow local nuances and inputs.

4. The focus on personalized nutrition limits the broad attention required for public and planetary health.

5. The privilege of education comes with a responsibility towards society.

6. The rationale behind women's empowerment should be independent of household interests.

Propositions belonging to the thesis, entitled

Fruggies for All - Evaluation of an integrated nutrition-sensitive project targeted to increase fruit and vegetable consumption in urban Vietnam and Nigeria

Giulia Pastori
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Fruggies for All

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Thesis

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Chapter 1

General introduction

A healthy diet includes the consumption of fruits, vegetables, legumes, nuts and whole grains, and limited intakes of free sugars, fats and salt (1). Healthy diets help preventing malnutrition in all its forms (2,3) and diet-related non-communicable diseases (NCDs), such as type 2 diabetes, cardiovascular diseases and cancer (1). However, malnutrition and NCDs are highly present worldwide. In the last decades, the majority of high-income countries (HICs) experienced an increase in diet-related NCDs and have been making the effort to move towards higher intakes of fresh and minimally-processed foods with support from programs and policies (4,5). On the other hand, presently, many low- and middle-income countries (LMICs) also started experiencing the increase of diet-related NCDs, often shifting from insufficient intake of foods to diets rich in salt, fats and refined carbohydrates, a phenomenon defined as the “nutrition transition” (6). These changes are also associated with the coexistence of undernutrition, overnutrition and micronutrient deficiencies in the same population, which has been increasing in many LMICs (7). Worldwide, around 2 billion people are micronutrient deficient (8) and, out of 126 LMICs, 48 countries present high prevalence of wasted and stunted children (9), thin women, and overweight adults and children (10,11). This coexistence of all forms of malnutrition is particularly prevalent in sub-Saharan Africa, south Asia, east Asia and the Pacific. In sub-Saharan Africa 44% of children are stunted, 15% are wasted, 13% of women are thin and at the same time 28% of women are overweight or obese (10).

In order to revert these nutritional challenges in LMICs, consumption of nutritious foods such as fruits and vegetables (FV) need to be promoted while unhealthy food should be discouraged (12). Promoting FV consumption is a pertinent issue and requires comprehensive approaches (13).

Why is it important to consume fruits and vegetables?

There is consensus on the health benefits of FV consumption due to their low energy- and high nutrient-density, with their content of minerals, vitamins, antioxidant and fibre (14). In addition, increased use of FV may replace the consumption of unhealthy foods, such as energy-dense snacks and refined grains (15). FV intake is protective against certain types of cancer, cardiovascular diseases and other diet-related NCDs, such as type 2 diabetes and obesity (15,16). Diets low in fruit intake are the third dietary risk factor for Disability-Adjusted Life Years (DALYs) after those high in sodium and low in whole grain intake (17). Diets low in vegetables are not in the top 5 dietary risk factors, probably due to a lack of epidemiological evidence, but low vegetable intake is likely to contribute to the same NCDs as fruits (18) . Globally, 2 million deaths and 65 million DALYs are attributable to low fruit intake, and 1.5 million deaths and 34 million DALYs are attributable to low vegetable intake per year (19). Especially, LMICs have the highest prevalence of diet-related deaths and DALYs for cardiovascular diseases responsible of 55% and 60% respectively. In Southeast Asia and Western sub-Saharan Africa low FV intake combined are the leading dietary risk factors of deaths and DALYs (19). Overall, the Global Burden of Diseases study in 2019 reports the need to reduce diet-related risks and highlights the protective role of FV intake (17). Therefore, increasing FV consumption is one of the major steps towards a healthier population worldwide, especially in LMICs.

The World Health Organisation (WHO) has been advising high consumption of FV for more than 20 years. WHO recommends a daily intake of 400g (or 5 portions) as part of a healthy diet to protect from all-cause mortality and all forms of malnutrition (20). Yet, it appears that the consumption of FV is not optimal across populations (21). Globally, the average intakes is estimated to be 81 g/day of fruits and 190g/day of vegetables (22). Particularly, only 20% of population living in LMICs meet the WHO recommendations, and sub-Saharan Africa is one of the world region which is least likely to meet the WHO recommendations (23). Moreover, solely 27% of southeast Asian countries and 7% of west African countries meet the recommended intake of vegetables (24). Therefore, understanding the determinants of consumption is relevant to leverage practices that promote FV consumption.

What are the reasons for consuming insufficient amounts of fruits and vegetables?

FV consumption is influenced by multiple sectors and factors. The food system framework proposed by the High Level Panel of Experts of the World Committee on Food security (HLPE) clearly depicts how different sectors and actors interact and can contribute to dietary outcomes (25) (Figure 1.1). However, current food systems focus on producing enough food but fail to provide healthy and sustainable diets to all (8). For instance, in many LMICs mainly domestic agriculture drives food availability but governments have been subsidizing cereal production and not FV, subsequently decreasing production diversity (13). Therefore, food production and markets need to make more FV available to ensure consumers can choose and consume them in sufficient amounts (26,27), depending on their individual behaviours. Therefore, a food system transformation is required to provide healthier diets and to this aim a consumer-centred perspective has been proposed (28).

Within the food system, the food environment is defined as “the interface that mediates people’s food acquisition and consumption within the wider food system. It encompasses external dimensions such as the availability, prices, vendor and product properties, and promotional information; and personal dimensions such as the accessibility, affordability, convenience and desirability of food sources and products” (29). The external drivers and the personal drivers are the key factors within the food system framework which directly determine consumer’s choices and consumption. These two dimensions interact and affect each other influencing individual choices being only one part of what determines consumption and dietary patterns.

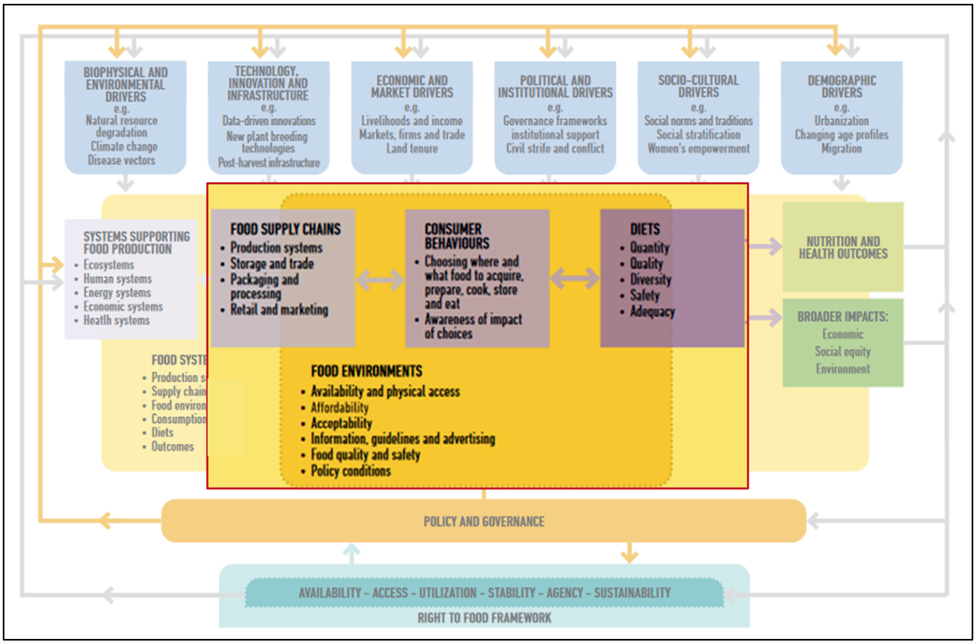

Figure 1.1 Food system framework with focus on food supply chains, food environments, consumer behaviours and diets, adapted from HLPE (30).

Extensive research has been conducted to investigate determinants of FV consumption on the food environment level. Especially in growing economies, supply-side factors play an important role in understanding consumption patterns (31). Types of food outlets and food availability and affordability affects food choices and consumption (32,33). Although the majority of the evidences related to food environment factors come from HICs, the available research from LMICs suggests that proximity to markets and shops, as well as their typology, can influence food intake (34). Convenience, in terms of proximity to the markets (35,36), storage facilities (33,34), availability and easiness of preparation (37) are reported to be important factor for FV consumption.

At individual level, a systematic review (38) reported that affordability is one of the main drivers of FV consumption in LMICs because of seasonal price fluctuations (39–41) and purchasing power of the households (36). Moreover, personal taste (35), preferences, knowledge (42,43) and health outcomes expectations (36) affect FV intakes among low-income populations in both HICs and LMICs. Food safety concerns (42,43) and cultural believes and taboos (42,43) were determinants more predominant in LMICs.

In summary, the determinants of FV consumption are multiple, multi-faceted and vary across countries. Yet, the investigation of food environment and FV consumption in African and Asian countries has been limited. Nevertheless, interventions to increase FV consumption need to be informed by such research. For this reason, in this thesis we focus on FV consumption in LMICs using Vietnam and Nigeria as specific cases.

What can be done to increase fruit and vegetable consumption?

There are several examples of policies and programs for increasing FV consumption. Policies and subsides promoting consumption of healthy foods, such as FV, have been implemented in different countries. Examples are mass media campaigns, school food policies and worksite wellness programs (44). For instance, the EU School Fruit Scheme has been successful in increasing daily FV intake among children (45). Additionally, the provision of vouchers to low-income groups to purchase FV have been implemented and increased consumption (46). The provision of cash transfer programs improved children nutritional status and dietary diversity in LMICs (47). Interventions that aimed to change the food environment and consumption behaviours including FV consumption have been found effective. These are public health interventions that promoted FV consumption and have been implemented mainly targeting children or vulnerable population groups (patients, pregnant women). These interventions include school nutrition programs, nutrition education and a few interventions on nudging FV consumption at the market level. School feeding and gardening programs have shown to increase FV intake in children, improve nutritional status, education and health and can also have a spill over effect on parents (48,49). A review on interventions that targeted parents to increase children FV consumption found that clear messages with the addition of multiple strategies to reinforce the messages were effective (50) but parent nutrition education interventions was also found to have a limited effect in children FV intake (51). In general, intervention strategies implemented at schools and workplaces, communication campaign as well as home production were effective community-based strategies to improve FV consumption (52). These interventions have the potential to modify and influence food consumption (53) towards healthier choices but more effort is needed, as these strategies are inconsistently implemented in LMICs (54).

Overall, as mentioned, consumer's choices and consumption of FV are the result of a complex mix and interaction of drivers and determinates. Therefore, integrated approaches, addressing multiple barriers and facilitators, and targeting the several actors who are involved in FV production, delivery and consumption, are needed. In the last decades, interest in integrated approaches of nutrition-sensitive intervention to improve diet quality at the population level has been evolved (55). Nutrition-sensitive interventions are interventions that target the underlying determinants of nutrition to improve nutrition and food security

(56). Nutrition is enhanced by addressing sectors other than health such as agriculture, education, or social protection. Multi-sectoral nutrition sensitive interventions, which address several determinants and barriers of consumption, are considered successful programs in improving diet quality (57). For instance, cash transfer integrated with behaviour change communication and services for health prevention and hygiene were more effective to improve children nutritional status compared to only cash transfer (47). Diversification of interventions could reinforce each other and address different underlying determinants (58). Secondly, applying participatory approaches to these interventions may make them more effective because determinants of FV consumption are highly context specific. Therefore, co-creation approaches of nutrition sensitive-interventions have been developed (59,60). Such participatory approaches which involve individuals, help to identify and consider cultural and context specific drivers to better tailor interventions (61). This may increase the adoption and acceptability of healthy behaviours, and subsequently the probability of reaching the desired impact on the target population.

To conclude, improving FV consumption requires holistic and participatory approaches intervening on the food environment, consumers choices and preferences. A deeper understanding of consumers choices and food environments would contribute to the needed food system transformation for enabling healthier choices, and developing supporting interventions and policies (28).

Fruit and Vegetable intake in Vietnam and Nigeria project

The nutrition-sensitive project “Fruit and vegetable intake in Vietnam and Nigeria” (FVN) started in 2019 and ended in 2021, aiming to increase FV consumption of adults living in peri- and urban areas of Hanoi, Vietnam, and Ibadan, Nigeria. The FVN project responds to the challenge of improving poor quality diets being the major cause of all forms of malnutrition and diet related NCDs, using a food system approach. The food systems of the two countries are described in Box 1.1-1.2.

FVN project areas

The FVN project took place in an urban and a peri-urban neighbourhood in Hanoi, Vietnam, and Ibadan, Nigeria to enable comparisons of market and consumer purchasing dynamics. The selected areas were found eligible based on the high density of people with a low socioeconomic status, the proximity of several types of markets and limited donor or other research activity. Within Hanoi, the neighbourhoods of Đống Đa and Hà Đông were selected to represent an urban and peri-urban, respectively (Figure 1.2). At the end of the project, the neighbourhoods Nam Từ Liêm (urban) and Thanh Trì (peri-urban) were selected as control areas. In Ibadan, Abàeja and Bagadajé neighbourhoods were selected to reflect the urban and peri-urban neighbourhoods, respectively (Figure 1.3). At end-line, the control areas of Apete (urban) and Ariyibi (peri-urban) were selected. In both countries, the control areas were identified for the comparable characteristics of the food environment, prevalence of low-income households, and similar sociodemographic characteristics of the population.

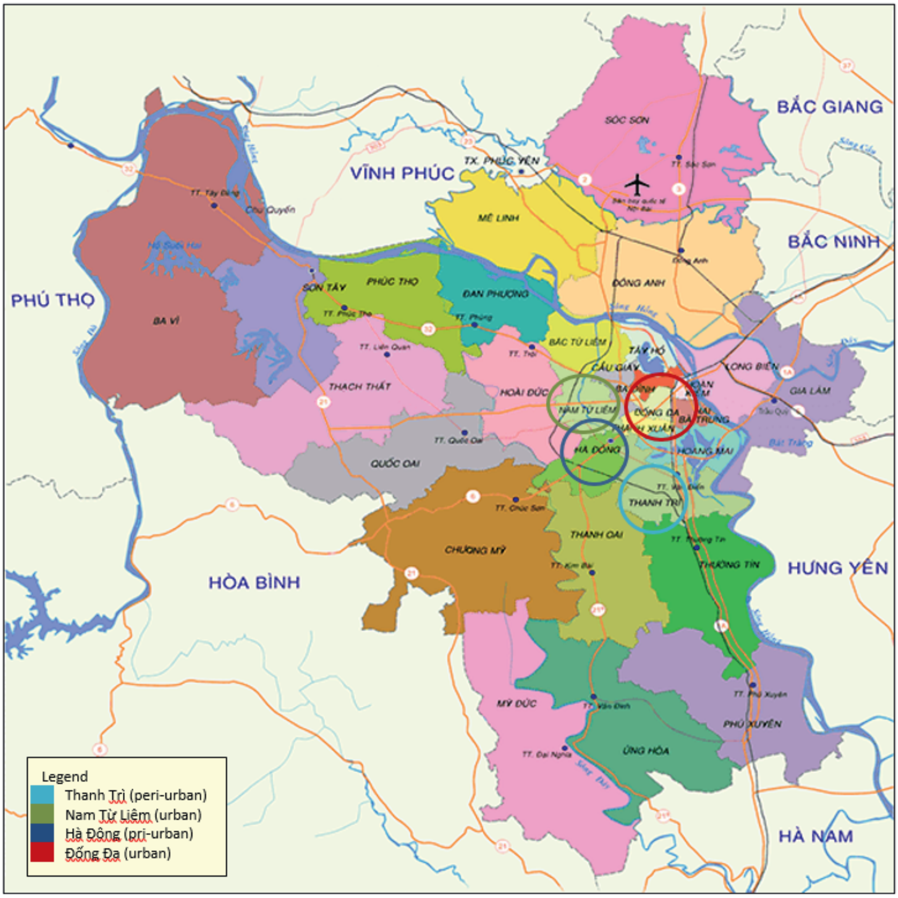

Figure 1.2 Map of Hanoi, Vietnam, with selected study areas.

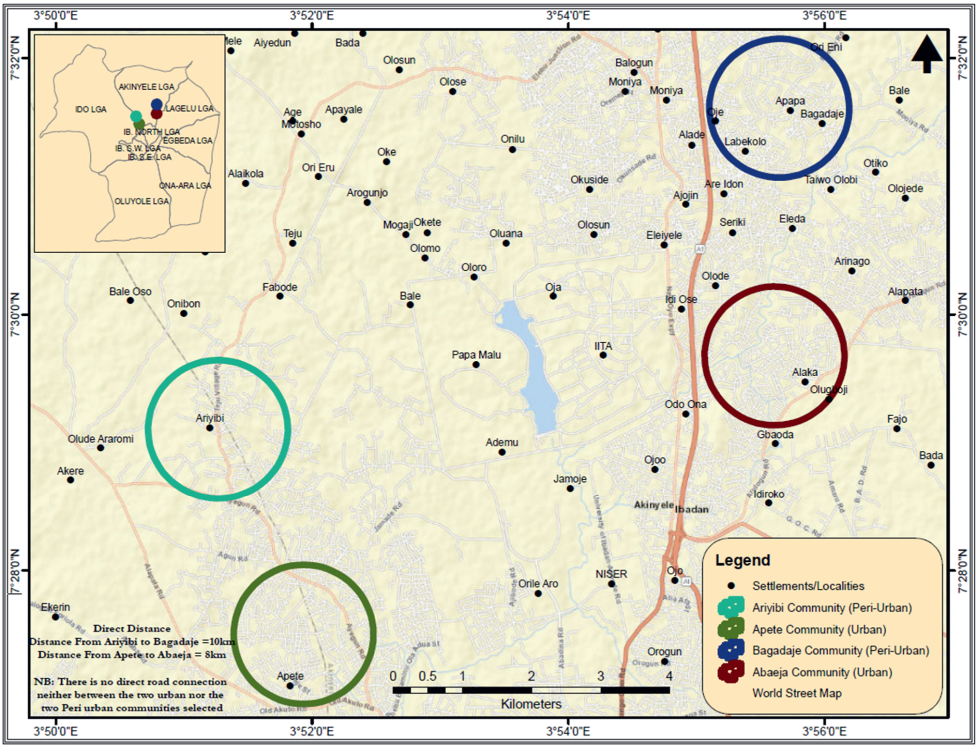

Figure 1.3 Map of Ibadan, Nigeria, with selected study areas.

The FVN project design

The FVN project's main objective was to increase FV consumption of low-income populations through consumer-oriented approaches aiming at addressing accessibility, affordability and acceptability of FV in Vietnam and Nigeria. This was done through the implementation of three types of interventions, which were co-created (62) with the target population using a user-centric approach (28) to tailor the interventions based on contexts specific needs and barriers. The FVN project consisted of a parallel study design, meaning that the design was the same for both countries, including two work packages.

Work package 1 aimed to evaluate the overall impact of the three interventions on FV intake. This was done in three different ways: a baseline assessment at the start of the project to assess FV consumption of the target population (2019); monitoring FV consumption of the target population throughout the interventions (2020-2021); an end-line assessment at the end of the project to assess FV consumption including a control group to compare the intakes with the target population (2021).

Box 1.1 Vietnamese food system

Since 1986 a series of policies and reforms, known as *doi moi* (‘renovation’), have been implemented in Vietnam and started a fast economic development of the country. In the last four decades due to the *Doi moi* reforms poverty decreased (63), while living standards of the majority of the Vietnamese population increased; infant mortality rate decreased from 47 per 1000 live births in 1980 to 16 in 2021 (64), and extended life expectancy from 66 in 1980 to 75 in 2020 (65). However, Vietnam remains economically insecure, one of the least urbanised countries in Southeast Asia and with poverty being one of the prior concerns (31,63).

Agricultural development has been a main focus of the reform, resulting in feeding the growing population, alleviating rural poverty and increasing food export, mainly of rice (66). Since the *Doi moi* was implemented, total daily energy intake per person drastically increased, with a large increase of energy from animal products (357%, mainly pork) but a limited increase in vegetable products (14%) (67,68). Overall, in the last decades there has been an improvement in terms of abundance of food but a decrease in quality of the diet (69).

These reforms combined with economic growth have transformed the food environment, and subsequently changed food choices and consumption habits (70,71). Recently, the Vietnamese government has planned to close traditional markets replacing them with supermarkets to improve food safety (66). However, this increased the availability, accessibility and consumption of unhealthy foods and decreased the accessibility of nutritious food, such FV, especially for low-income urban populations (72). Low-income urban populations in Hanoi are still sourcing the majority of their food (70%) from informal markets and vendors, still consuming more fresh foods and limited ultra-processed food consumption (71). Women still prefer to cook and eat traditionally using food from informal markets (71). Nevertheless, it is predicted that diets will gradually change since younger generations have different preferences and tastes compared to the older generations which affect households consumption (70). These changes in the food environment and diet are expected to lead to an increase in malnutrition and diet-related NCDs (73).

Vietnam has a country-specific food based dietary guidelines developed by the Vietnamese National Institute of Nutrition (NIN) and the Ministry of Health since 1995 (74,75). They recommend increasing FV consumption but without providing a recommended daily amount. Nevertheless, in 2015 around 43% of the adult Vietnamese population consumed the recommended 5 portions a day (4,76). Data from the Vietnam national survey (2015) (77) and other studies (76,78) showed that on average the population consumed 2.9-4.3 servings a day of FV (1-1.3 servings of fruits; 2-3.0 servings of vegetables), with females consuming more fruits than males but a similar consumption of vegetables across the sexes. Although the mean intake is lower than the recommendation, FV intake is higher than in other South and Southeast Asian countries such as Bangladesh, India, Indonesia and Thailand. Furthermore, there is no large variation in fruit consumption across age groups, while older generations consume more vegetables than the younger ones (78). Bui et al (2016) found a difference across provinces, with the highest consumption in the urban area of Hanoi (79). Especially vegetable consumption is nowadays also linked to concerns about food safety especially for the high and unregulated use of pesticides (66). However, people are coping in different ways. Those who can afford it, go to the supermarket and buy imported foods, as considered a safer option. Alternatives are home-grown vegetables, also in the city, the creation of cooperatives, or continue going to the market buying from trusted farmers and vendors. The large use of pesticides in FV also resulted in a higher preference of animal source foods (31). Food safety is currently a policy priority in Vietnam (66) to improve diets and access to safe and nutrition foods by 2030 (80).

Work package 2 included the three different interventions (Figure 1.4), developed based on data collected in work package 1 on the dietary intake and knowledge, attitude and practices around FV consumption of the study population, barrier analysis, product seasonality and market assessment of the studied areas.

Intervention A focused on accessibility and affordability of FV. The intervention was co-created with vendors and included improved point of sales and product display (Nigeria), improved marketing strategies (Vietnam and Nigeria), delivery of nutritional information to consumers (Vietnam and Nigeria), improved food safety and customer service practices (Nigeria) and set-up of a loyalty card system (Vietnam) (Appendix Figure A1.1-1.2). This intervention was implemented for eight months in both countries (December 2020 – July 2021 in Vietnam; February – October 2021 in Nigeria).

Intervention B focused on increasing affordability by implementing a coupon-based system. Coupons were handed out to consumers to enable them to buy selected fruits (Appendix Figure A1.3-1.4). The coupons were of two different monetary values (Vietnam: 30,000/60,000 Vietnamese dong; Nigeria: 400/800 Nigerian naira) to purchase different fruit items (8 in Vietnam and 9 in Nigeria) from selected FV vendors. In Vietnam, coupons were delivered to randomly selected sample households on a biweekly basis, first by a delivery service and then by community health workers two months after the project began. In Nigeria, sets of coupons were delivered to randomly selected sample households by project staff on a weekly basis. In both countries, coupons expired two weeks after they were received by households and could be redeemed at the participating vendors. This intervention was implemented for five months in both countries (February – July 2021 in Vietnam; June – October 2021 in Nigeria).

Intervention C focused on increasing acceptability of FV, through campaigns aiming to promote the importance of adequate daily FV consumption (Appendix Figures A1.5-1.6). These were co-created with consumers (59,60) through focus group discussions. In Vietnam, communication materials (pamphlets, posters) focused messaging around the health benefits of FV, their variety and seasonality, WHO recommended intake of 400 g/day, food safety and home production, and they were disseminated by local health centres through social media platforms, market events, training courses, and loudspeaker announcements. In Nigeria, messaging in the communication materials (pamphlets, posters, branded merchandise, jingles, dramas and expert talks) highlighted disease prevention, WHO recommended intake of 400 g/day, affordability, food safety, home production, variety and seasonality, and campaigns were carried out through radio stations, primary health care centres, religious centres and schools. This intervention was implemented for eight months in both countries (December 2020 – July 2021 in Vietnam; February – October 2021 in Nigeria).

Box 1.2 Nigerian food system

Nigeria is the most populated African country with than 220 million people (96) of which about half are 18 years old or younger and live in rural areas (97,98). Nigeria has the largest and most established economy in West-Africa and agricultural productivity has been growing steadily since 2000 (98,99). In the last decades, the prevalence of poverty dropped from 60% of population living below 1.90 dollar a day in 2002 to 38% in 2022 (97).

However, the majority of the young population is unemployed, the country has the largest number of people living in extreme poverty globally and there is a high prevalence of food insecurity (99). It has been reported that households spend on average 65% of their income on food, and the cost of nutritionally adequate diets is 92% as percent of daily per capita household food expenditure (100). Moreover, 7-9% of the population in the lowest income quintile often experience lack of food (101), and in 2020, 96% of the population was unable to afford a healthy diet (102). In general, Nigeria is not able to meet the food requirements of its population with only local production, and therefore relies on imports of products such as rice, wheat and fish (74). Currently, available FV are sufficient to meet the requirements for only half of the population (103) not including that 8% of fruit and 14% of vegetables locally produced is not consumed because it is wasted along the supply chain (104).

Nigerians face dietary inequalities, such as difficulty in accessing high quality food in terms of nutrient-dense and safe, which is reflected by the coexistence of all forms of malnutrition (105). In the last decades, national surveys showed a stagnation or slow decline in prevalence of child stunting and adult female thinness, while overweight and obesity in adults are increasing (106). Specifically, female underweight decreased from 13% in 2000 to 8.8% in 2020 and overweight increased from 24% to 38.7% in the same period, with obesity similarly showing an increasing trend (97). Overall, in rural areas undernutrition and stunting remain more prevalent, while overweight and obesity are on the rise in urban areas (106). Over the last decades, malnutrition has been the first risk factor that drives death and diseases in Nigeria with a small decrease in the period 2009 to 2019 (107). In the same period the impact of high blood pressure and high body mass index as risk factors increased (108).

Nigerian dietary habits have been changing in the last decades. Grains and legumes consumption decreased from 1990 to 2010; while consumption of sugar-sweetened beverages increased over the same period (103). The shift of consumption towards unhealthy diets is also evident from the low consumption of FV. Only 18% of the Nigerian population meet the requirement for fruit intake. In 2019, 35g/d of fruits and 93g/d of vegetables were consumed on average (97). In Nigeria, diets low in FV are one of the leading dietary-related risk factors for mortality (108).

The Nigerian government is taking actions to address the high prevalence of malnutrition and the subsequent health problems. From 2018, the Nigerian country-specific food based dietary guidelines promote healthy, diverse and seasonal diets (109) but do not include specific recommended amounts for FV. Additionally, policies were implemented to support the reduction of unhealthy eating. In 2017, a sugar tax was implemented on sugar sweetened beverages (97). Transforming food system by expanding the quality and variety of food products (99), improving availability and affordability of nutritious foods and guiding consumers towards healthier choices through education and labelling (110) are the goals of Nigerian programs and policies for both urban and rural areas.

All three interventions were implemented at the same time in the study areas with the hypothesis that bundling different interventions that address multiple determinants of FV consumption would be more beneficial for increasing their consumption compared to the implementation of individual intervention. This thesis focuses on the overall evaluation of the FVN project on FV consumption, whereas separate studies evaluated the single interventions on intermediate outcomes and are not reported in this thesis.

Fruit and vegetable consumption assessment

Increasing FV consumption requires interventions based on a holistic approach. The monitoring and the evaluation of nutrition-sensitive interventions are important for the identification of successful strategies and approaches. However, notwithstanding, current approaches to evaluating the consumption of FV are limited in methods used to quantify consumption and in data available worldwide (81). For this reason, validated indicators are needed to assess actual FV intakes as final outcomes of the interventions.

There is a wide range of methods used to assess dietary intake at the population level. These are 24-hour recalls, food frequency questionnaires, weighted food records and dietary records (82). From dietary intakes, several scores can be derived such as Minimum Dietary for Women (MDD-W) (83), Global Dietary Recommendation (GDR) score (84), Global Diet Quality Score (GDQS) (85), Healthy Dietary Index (HDI) (86), World Index for Sustainability and Health (WISH) (87), to assess food group consumption and diet quality. These scores have been validated as indicators of dietary diversity, micronutrient deficiencies, sustainability and risk of diet-related non-communicable diseases, or combinations thereof. Specifically, for FV consumption, no single indicator exists but the diet quality scores include several components of FV.

Overall, the assessment of actual FV intake presents some difficulties. To assess habitual intakes, multiple observations are needed for a good estimation (88), which requires a large amount of resources. Moreover, seasonality plays an important role in FV consumption, especially in regions where consumption is strongly linked to short chain food availability (89,90). This increases the variation of consumption over the year, and it may not provide a general picture of the diet unless regular assessment of consumption is performed or representative data for each season are available. Moreover, country specific food practices such as out of home consumption affects the estimation of the portions and actual ingredients consumed (91), especially for vegetable intake. Also, the majority of dietary assessments are based on memory, which are prone to recall bias (82). This leads to underestimation of food items that are rarely consumed, for example fruits. Finally, also food production at country level has often been used as a predictor of intake (92,93) but this does not take into account intrahousehold food distribution and waste at household level.

In this context, there is an obvious need of harmonized methods and indicators for the evaluation of FV intakes, in order to allow comparability across countries and within populations. Our study tried to address these methodological issues proposing a simple, intuitive and low burden indicator that is accessible to all, especially in low-resource settings.

The complexity of the underlying causes of food consumption and the diversity of food environments across countries and within populations cannot be generalized as also consumers characteristics are local and context specific (94). Therefore, a suitable approach would be to investigate specific contexts and develop solutions upon the findings. This contributes to build a body of evidence needed to support possible changes. In this thesis, Hanoi and Ibadan were chosen as specific contexts, and the thesis forms part of work package 1 of the FVN project.

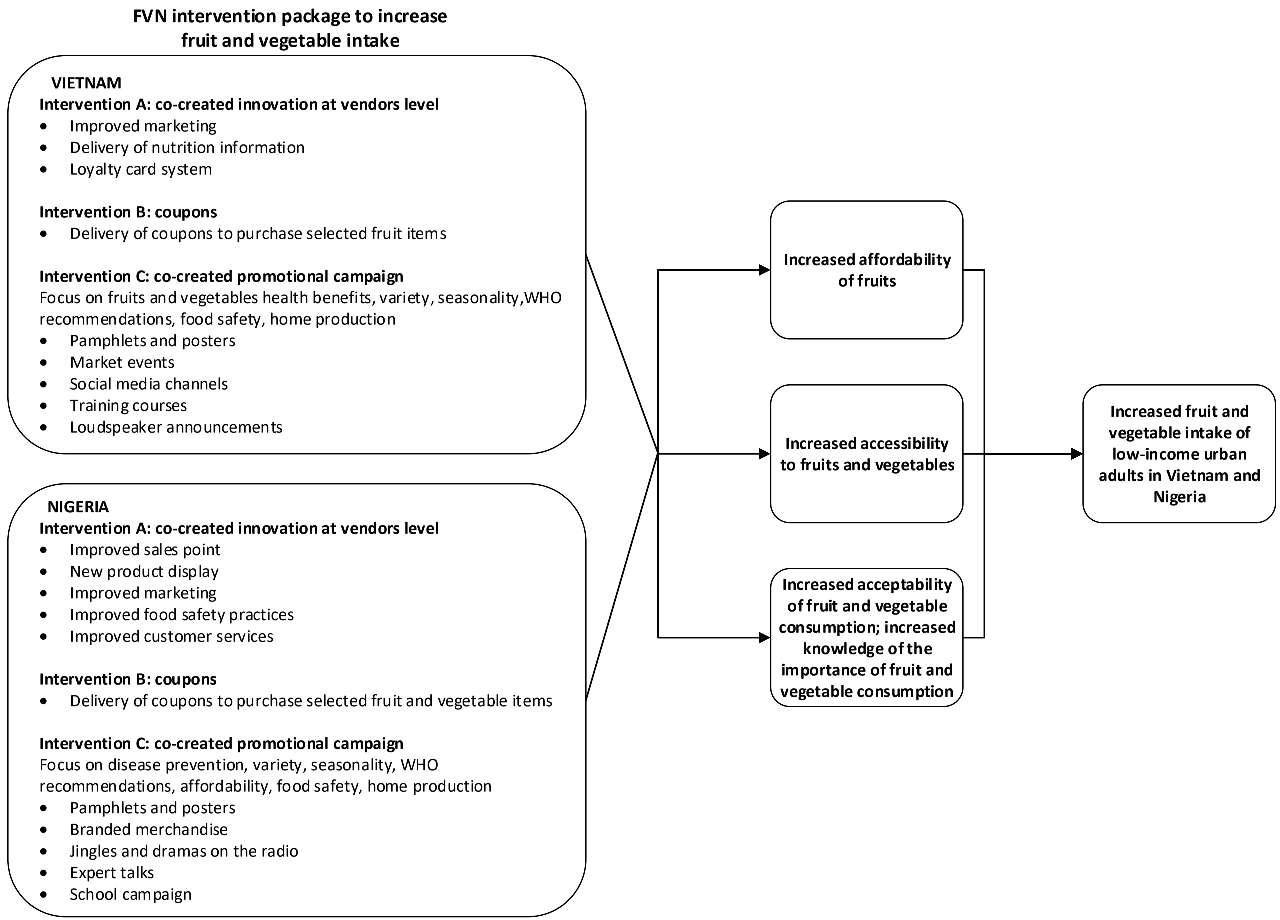

Figure 1.4 FVN intervention descriptions and pathways to increase fruit and vegetable intake

Aim and objectives

The overall objective of this thesis is to evaluate a nutrition-sensitive project that aimed to increase FV consumption of low-income Vietnamese and Nigerian adults living in urban and peri-urban Hanoi and Ibadan.

The following specific objectives are addressed:

1. To characterize dietary patterns of consumers living in urban and peri-urban Hanoi, Vietnam and Ibadan, Nigeria.

2. To validate a FV score as simple indicator to assess FV consumption at population level.

3. To monitor FV consumption trends of low-income urban and peri-urban adult Vietnamese and Nigerian females during the FVN project.

4. To evaluate the effect of the FVN project on the FV consumption of urban and peri-urban low-income adults in Hanoi, Vietnam and Ibadan, Nigeria.

Thesis outline

To reach the above objectives, this thesis describes four studies.

Chapter 2 explores the dietary patterns among low-income adults living in urban and peri-urban areas in Hanoi and Ibadan and evaluates the quality of the diet of the identified patterns. Additionally, it describes the consumer's characteristics of each dietary pattern, investigating the association between consumption and sociodemographic characteristics. In this chapter we used data from the baseline FVN assessment (2019).

Chapter 3 investigates the relative validity of the FV component of the Global Dietary Recommendation (GDR) (84) score collected with the Dietary Quality Questionnaire (DQQ) (95) as indicator to assess FV consumption at the population level. In this chapter we analysed data from the end-line FVN assessment (2021).

Chapter 4 explains how FV consumption of Vietnamese and Nigerian females changed during the period of the FVN project and examines the association with the degree of exposure to the three interventions. In this chapter we used data on dietary intakes from the FVN monitoring assessment (2020-2021).

Chapter 5 evaluates the overall FVN project, investigating the difference in FV consumption between the group living in the FVN interventions areas and a group not exposed to the interventions (control), and between different degree of exposure to the interventions. In this chapter we used data on dietary intake from the end-line FVN assessment and information on the exposure to the interventions (2021).

Chapter 6 summarizes the main results and provides a general discussion, synthetizing the key findings and reflecting on their broader implications, current evidence and potential future research and projects.

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APPENDIX

Figure A1.1 Loyalty card delivered for intervention A of FVN project in Vietnam

Figure A1.2 Display and umbrella created with and used by fruit and vegetable vendors for FVN intervention A in Nigeria

Figure A1.3 Coupon delivered for intervention B of FVN project in Vietnam

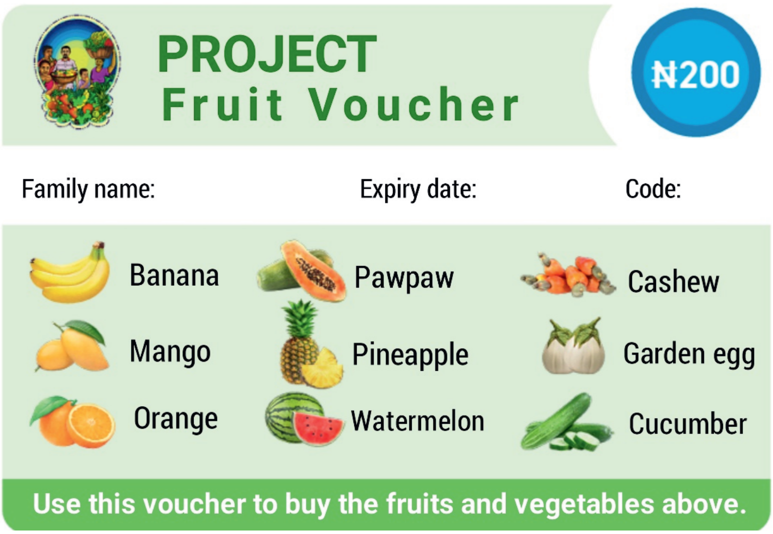
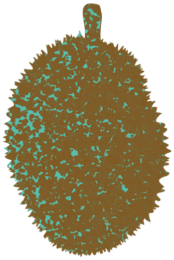


Figure A1.4 Coupon delivered for intervention B of FVN project in Nigeria

Figure A1.5 Poster developed for the fruit and vegetable promotional campaign (FVN intervention C) in Vietnam

Figure A1.6 Aprons developed for the fruit and vegetable promotional campaign (FVN intervention C) in Nigeria



Chapter 2

Identification and characterization of dietary patterns of low-income urban adults in Vietnam and Nigeria

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ABSTRACT

Background A thorough understanding of dietary patterns and their drivers is needed to facilitate food system transformations to provide sustainable healthy diets to everyone. *Objective* To identify dietary patterns of low-income adults in urban Vietnam and Nigeria, and to characterize consumers and the diet quality of these dietary patterns.

Methods We used Latent Class Analysis to characterize dietary patterns of low-income adults aged 18-49 years living in urban and peri-urban areas in Hanoi, Vietnam (n=397) and Ibadan, Nigeria (n=363). Food intake was assessed by duplicate quantitative 24-hour recalls and diet quality was assessed in terms of diversity (Food Group Diversity Score), risk of non-communicable diseases (Global Diet Quality Score) and micronutrient adequacy (Mean Probability of Adequacy). Latent class analysis with a bias-adjusted three-step approach was used to investigate the associations of sociodemographic characteristics and diet quality with dietary patterns.

Results In Vietnam, we identified three dietary patterns: “Animal based” (38% of the population), “Rice, legumes and vegetables” (31%) and “Rice, noodles and pork” (31%). Consumers differed in age, area, household size, marital and living standard, education, occupation and diet quality. Consumers with the “Rice, noodles and pork” dietary pattern had the lowest diet quality. In Nigeria, we identified three dietary patterns: “High intakes and vegetables” (39%), “Low intakes” (36%), and “Dairy and sugar” (25%). Consumers did not differ in sociodemographic variables. Consumers of the “Low intakes” pattern had the least diverse and adequate diet.

Conclusions In each setting, we identified and characterized different consumer groups with unique dietary patterns. Understanding these consumer groups and the drivers of their food choice will help to identify tailored interventions to diversify diets and to prevent unhealthy consumption patterns.

INTRODUCTION

Current food systems fail to provide sustainable healthy diets (1) for everyone, everywhere. Moreover, 3 billion people cannot afford healthy diets (2), which are associated with 11 million premature adult deaths each year and key drivers of malnutrition in all its forms (3). Undernutrition remains a critical concern in the world's poorest, and overweight and obesity are increasing in nearly all countries, especially in low- and middle-income countries (4).

Consequently, the transformation of food systems to ensure the supply of sustainable healthy diets for everyone is one of the largest challenges faced today. This transformation includes addressing consumer demand, and drivers of food choices at individual, household and community levels (5); and in the food environment, entailing what is available and accessible to consumers to favor healthier diets (6). This requires a thorough understanding of food consumption patterns and their drivers in various regions at different stages of the nutrition transition.

Context-specific understanding of dietary patterns and inadequacies in food consumption can inform and monitor food system transitions by identifying the main dietary and nutritional gaps. This can inform the co-design, testing and evaluation of scalable innovations in the food environment-consumer nexus and support policies to foster and achieve consumption of sustainable healthy diets (5). Additionally, it is important to identify consumers at risk for dietary inadequacy who should be targeted through nutrition interventions (7).

Traditionally, dietary analyses have focus on food group consumption or nutrient intakes (8,9). However, considering that people do not consume individual foods or nutrients in isolation, a comprehensive analysis of overall dietary patterns provides more informative insights (10,11). Dietary pattern analysis categorizes individuals into different dietary pattern groups based on their actual consumption of food groups. There are *a priori* methods where the dietary patterns are predefined based on diet-disease associations, such as the Healthy Eating Index, and *a posteriori*, data-driven methods used to identify existing patterns. Among the latter, Principal Component Analysis is often used to identify patterns derived from the association between dietary variables (12). Another method is Latent Class Analysis (LCA), which allows the characterization of groups of individuals into mutually exclusive dietary patterns assuming the existence of latent factors underlying the overserved variables (13–15).

The current study aimed to identify dietary patterns of low-income adults in urban and peri-urban Hanoi, Vietnam and Ibadan, Nigeria using LCA, and to characterize consumers and diet quality of these identified dietary patterns.

METHODS

Study population

This study uses baseline data from the project "Fruit and vegetable intake in Vietnam and Nigeria" (FVN), which aimed to increase fruit and vegetable consumption of low-income urban populations in Vietnam and Nigeria through the implementation of food system innovations (16). The targeted households were randomly selected from a list of low-income households in one urban and one peri-urban area: Đống Đa and Hà Đông in Hanoi, Vietnam, and Abàeja and Bagadajé in Ibadan, Nigeria, respectively. The areas were selected for the high prevalence of low-income households. The study population included females and males aged 18-49 year, non-pregnant, non-lactating, living in the selected areas, and willing to be interviewed on two separate occasions. In each area 100 households were selected with an eligible woman and if available a male household member. Ethical approvals for the FVN project were obtained prior to the start of the study from Hanoi Medical University Institutional review Board in Hanoi (45-18/HMU-IRB) and University of Ibadan/University College Hospital Ethical Review Committee (UI/UCH-ERC) in Nigeria (HNHREC/05/01/2008a) and all participants signed the informed consent.

Dietary assessment

Dietary intake was assessed with a multi-pass quantitative 24-hour recall (24hR) method (17,18) administered in February-March 2019 in Vietnam, and in March-April 2019 in Nigeria. 24hRs were conducted in duplicate on non-consecutive days with a difference of at least two days and at most one month between the two recalls. During home visits, respondents were asked in the presence of the cook to recall all foods and beverages they consumed in and outside their home from the time of waking up the day preceding the interview to the time of waking up on the day of the interview. Details on ingredients, methods and place of preparation, together with quantity and frequency of consumption of each ingredient were collected. Quantities were estimated with weighing similar ingredients with a kitchen scale (LP-B series for Vietnam; Camry EK5055 for Nigeria), if available in the households, or with equivalent volumes of water, volumes of dry foods like rice or flour, or monetary values. Conversion factors and edible portions were then applied to calculate the actual amount of food consumed. For foods and meals prepared out of home, standard recipes were created by the study teams and used to estimate out of home intakes. Food composition tables (FCT) were created for each country using the local FCT and values from FCTs from neighboring countries when needed (19–22). Energy and nutrient intakes were calculated by linking dietary data to the FCT using the nutrient calculation system Compl-eat™ (Wageningen University, Wageningen, the Netherlands, Version 1.0). Food and nutrient intake data from the duplicate recalls was averaged, except for individuals with only one 24hR (3 females and 3 males in Vietnam; 10 females and 10 males in Nigeria), for whom intake from only one recall was used. Next, having z-scores of energy intake calculated, data were cleaned by checking recalls with z-scores higher or lower than ± 2.58, and the highest and lowest 1% of the food amounts recalled. These were checked for discrepancies with the original paper questionnaires and corrected where possible. If no discrepancies were found, the plausibility of each case was discussed with a team of experts. All cases were judged plausible, and no data were excluded.

Consumer characteristics

For each individual, age, sex, education, occupation, and marital status were assessed by questionnaire. Area, household size, number of children, living standard index, and food insecurity were assessed with a questionnaire at household level, administrated to the female respondent. The living standard index was constructed from 31 variables (yes/no): 21 on the ownership of country specific durables and 10 on household's dwelling (three about source of drinking water, three about toilet facilities, four about fuel used for cooking), combined into a living standard index using Principal Component Analysis (23–25), and categorized into tertiles for interpretation. Bodyweight and height were measured in duplicate and body mass index (BMI) was calculated (weight divided by height^2) from the mean of the two measurements, as proxy of nutritional status (26).

Diet quality indicators

Diet quality was assessed in terms of dietary diversity, risk of non-communicable diseases and micronutrient adequacy. The semi-continuous sum of 10 food groups (supplementary material Table S2.1), referred to as Food Group Diversity Score (FGDS), proxy of micronutrient adequacy for the general population, was calculated (range 0-10) (27). The score was created from the average of the two days recalled and used as indicator of dietary diversity. The Global Diet Quality Score (GDQS) was used as indicator of risk of non-communicable diseases and nutrient adequacy (28). It is based on the consumption of 25 food groups; 16 healthy (GDQS-Healthy) and 9 unhealthy (GDQS-Unhealthy) (range 0-49) (29) (supplementary material Table S2.2). GDQS ≥23 is associated with a low risk of non-communicable diseases and of nutrient inadequacy, GDQS ≥15 and <23 indicates moderate risk, and GDQS <15 indicates high risk. GDQS was created from the first day of the 24hR (29) and prevalence of each GDQS risk score category was calculated. Lastly, Mean Probability of Adequacy (MPA) of calcium, zinc, thiamin, riboflavin, vitamin B6, vitamin B12, vitamin C, folate, niacin, vitamin A, iron was calculated as indicator of nutrient adequacy (30,31). These nutrients were selected because of the high prevalence of inadequate intake among women in low- and middle-income countries (32,33). Nutrient adequacy was calculated using the observed averaged nutrient intake, the average requirement (EAR) and its standard deviation. The full probability of adequacy was calculated for all nutrients except for iron for which the probability approach was used due to skewed distribution of iron requirements. For iron, a low bioavailability of 5% was assumed because of the high dietary content of phytate, which impairs iron absorption (34,35). Probability of adequacy was calculated using the PROBNORM function in R (version 4.2.1). The MPA was calculated for each individual as the average probability of adequacies for all selected nutrients.

Characterization of dietary patterns

LCA (36) was used to characterize dietary patterns in both countries separately. Unobserved ('latent') classes of people with dietary patterns were identified that are relatively homogenous within classes and distinct between classes with regards to food groups consumed. Intake of food items (167 for Vietnam and 125 for Nigeria) were grouped into food groups, following the Dietary Quality Questionnaire (DQQ) classification which is based on similarities in nutrient content (37). Country specific adjustments of the DQQ food groups were made based on the proportion of non-consumers, resulting in a total of 16 food groups in Vietnam and 21 food groups in Nigeria. Intakes of food groups (grams/day) were categorized, because many food groups had skewed distributions of intakes, a high proportion of non-consumers, and because LCA performs better with categorical variables. Intakes were categorized based on the percentage of non-consumers for each food group, as previously described (38,39). Food groups with <10% of non-consumers were categorized into two groups (intake "below the median" or "above the median", median based on all individuals); food groups with 10-50% of non-consumers were categorized into three groups ("non-consumers", and intake "below the median", "above the median" based on consumers only); and food groups with >50% of non-consumers were categorized into two groups ("non-consumers" or "consumers"). Food group categorization can be found in Supplementary Material (Tables S2.3 – S2.4). We ran models with 1-7 classes and determined the optimal number of classes based on minimized values of Bayesian (BIC) and Akaike (AIC) Information Criteria, likelihood ratio tests, entropy (R^2), parsimony (simpler model preferred), and model interpretability. In the selected model, only indicators that explained the variance of and contributed to the classification were kept based on a nominal p-value ($p<0.05$), R^2, and expected similarities in intakes in the total population. Subsequently, the assumption of local independence between indicators (using bivariate residuals [BVR]) was checked. We allowed for correlations between pairs of food groups with a BVR > 4. Dependence of observations between individuals from the same household was addressed using two-stage multilevel LCA and exploring higher level clustering by household (40). This function allows for the explanation of the heterogeneity of the dietary patterns at group level (household variable). Consumers were assigned to the identified specific dietary patterns based on the posterior class membership probabilities. Dietary patterns were named based on the probabilities of consumption of food groups. All analyses were performed using the advanced version of Latent Gold 6.0 statistical software (41).

Characterization of consumers and diet quality of dietary patterns

General characteristics and dietary quality indicators were reported for the total population and for each dietary pattern with mean (SD) for normally distributed continuous variables, median [IQR] for non-normally distributed continuous variables and percentages for categorical variables. To explore which socio-demographic characteristics were predictors of dietary patterns, we examined bivariate associations between characteristics and dietary patterns, using the bias-adjusted three-step approach (42) in Latent Gold. The bias-corrected maximum likelihood (ML) method was used for categorical variables and the Bolck–Croon–Hagenaars (BCH) method was used for continuous variables using a distal outcome formulation (43). The distal outcome formulation was used to directly model the class-specific distribution of the covariates of interest. In addition, we examined bivariate associations between dietary patterns and diet quality indicators, using the bias-adjusted three-step approach. Paired comparison in LatentGold was used to identify for which clusters the sociodemographic characteristics and diet quality indicators differed (p-value<0.05).

RESULTS

Study population

In Vietnam, nine of 397 individuals were excluded because these were duplicate entries of identical IDs and three were excluded because they were out of the eligible age range. The final study population included 385 individuals, with a similar distribution of sex and area (Table 2.1). Median [IQR] age was 39 years [34 - 45] and the majority was married (95%). More than half of the population had secondary education or higher (28% and 55%, respectively), and food insecurity was experienced by only 4% of the population.

In Nigeria, 19 of 363 individuals were excluded because they were pregnant or lactating and one person was excluded because she/he was out of the eligible age range. The final study population included 344 individuals with a similar distribution between urban and peri-urban areas (Table 2.2). Sixty-four percent of respondents was female, and the mean (SD) age was 35 years (±9). The majority of the population was married (73%), had secondary education or higher (46% and 24%, respectively) and most individuals experienced food insecurity during the last year (68%).

Table 2.1 General characteristics of the total population and stratified by dietary pattern, Vietnam[1]

	Total population	"Animal based"	"Rice, legumes and vegetables"	"Rice, noodles and pork"	p-value [2]
n	385	149	116	120	
Age in years, median [IQR]	39.0 [34.0, 45.0]	38.0 [33.0, 44.0][a]	42.0 [36.8, 46.0][b]	39.0 [34.0, 44.0][a]	**<0.001**
Females, %	51.2	43.6	51.7	52.5	0.28
BMI, median [IQR]	21.7 [2.6]	21.8 [2.6]	21.9 [2.4]	21.4 [2.7]	0.31
Peri-urban[3], %	49.4	72.5[a]	44.0[b]	25.8[c]	**<0.001**
Household size, mean ±SD	5.0 ± 2.1	4.7 ± 1.3[a]	4.7 ± 1.3[a]	5.2 ± 1.5[b]	**0.03**
Number of children, mean ±SD	2.1 ± 0.9	1.8 ± 0.8[a]	2.2 ± 0.7[b]	2.2 ± 1.1[b]	**<0.001**
Marital status, %					**<0.001**
Single	4.7	4.0[a]	2.6[b]	7.5[b]	
Married, monogamous	94.5	96.0	95.7	91.7	
Separated/divorced or widowed	0.8	0.0	1.7	0.8	
Living standard, %					**0.01**
Low	32.2	40.3[a]	33.6[a]	20.8[b]	
Medium	34.0	30.2	34.5	38.3	
High	33.8	29.5	31.9	40.8	
Education, %					**<0.001**
No formal education	3.6	0.7[a]	2.6[b]	8.3[ab]	
Primary	13.5	8.7	19.0	14.2	
Secondary	28.1	23.5	29.3	32.5	
Above secondary	54.8	67.1	49.1	45.0	
Occupation, %					**0.01**
Skilled	44.4	53.0[a]	43.1[b]	35.0[ab]	
Unskilled	41.6	37.6	38.8	49.2	
Own business	4.9	2.7	9.5	3.3	
Unemployed	9.1	6.7	8.6	12.5	
Experienced food insecurity, %	3.9	1.3	5.2	5.8	0.38

[1] Data are presented as mean ± standard deviation (SD), median [interquartile range] (IQR) or percentage; [2] p-value of test of bivariate associations between descriptive variables and dietary patterns, using bias-adjusted three-step approach in LatentGold software; [3] Peri-urban versus urban area; [a,b,c] different superscripts indicate a $p<0.05$ for pairwise difference for categorical variables the superscript refers to all categories. p-values are reported in Supplementary materials Table S2.8.

Table 2.2 General characteristics of the total population and stratified by dietary pattern, Nigeria[1]

	Total population	"High intakes and vegetables"	"Low intakes"	"Dairy and sugar"	p-value[2]
n	344	134	124	86	
Age in years, mean ±SD	35.0 ± 8.7	34.4 ± 8.9	35.3 ± 9.0	35.5 ± 8.2	0.41
Females, %	64.2	61.2	62.9	70.9	0.20
BMI, median [IQR]	22.9 [20.5, 26.7]	22.5 [20.3, 26.0]	23.1 [20.4, 26.3]	23.2 [20.7, 29.3]	0.19
Peri-urban[3], %	49.1	51.5	47.6	47.7	0.31
Household size, mean (SD)	5.3 ± 2.0	5.3 ± 2.0	5.2 ± 1.9	5.6 ± 2.2	0.39
Number of children, mean (SD)	3.3 ± 1.7	3.2 ± 1.5	3.3 ± 1.7	3.4 ± 1.8	0.79
Marital status, %					0.86
Single	17.7	18.7	17.7	16.3	
Married, monogamous	73.3	71.6	74.2	74.4	
Married, polygamous	7.0	6.0	7.3	8.1	
Separated/divorced or widowed	2.0	3.7	0.8	1.2	
Living standard, %					0.25
Low	34.9	31.3	32.3	44.2	
Medium	33.1	34.4	34.7	29.1	
High	32.0	34.4	33.1	26.7	
Education, %					0.28
no formal education	3.2	3.7	3.2	2.3	
primary	27.0	20.1	31.5	31.4	
secondary	45.9	50.7	41.9	44.2	
above secondary	23.8	25.4	23.4	22.1	
Occupation, %					0.27
skilled	34.9	31.3	36.3	38.4	
unskilled	18.6	23.9	13.7	17.4	
own business	37.5	38.1	37.1	37.2	
unemployed	9.0	6.7	12.9	7.0	
Experienced food insecurity, %	67.7	64.2	66.1	75.6	0.14

[1] Data are presented as mean ± standard deviation (SD), median [interquartile range] (IQR) or percentage; [2] p-value of test of bivariate associations between descriptive variables and dietary patterns, using bias-adjusted three-step approach in LatentGold software; [3] Peri-urban versus urban area

Characterization of dietary patterns

For Vietnam, we identified three dietary patterns based on fit statistics and model interpretability. Further details of the model selection are provided in Supplementary materials (Table S2.5). We named the first pattern “Animal based” (38% of population) because individuals in this pattern had high probabilities of consumption of ruminant red meat, fish, and poultry, although not of non-ruminant meat (Figure 2.1, Supplementary materials Tables S2.6-S2.7). This pattern was also characterized by high probabilities of consuming fruits (including vitamin A-rich, citrus and other fruits) and sweet foods and drinks. Total energy intake was lowest in this pattern (1,542 kcal/d, Supplementary materials Table S2.7), with the highest protein intake relative to the total energy. We named the second pattern “Rice, legumes and vegetables” (31% of population) because individuals had high probabilities of consuming rice and rice products, dark green leafy vegetables, but also oils and fats, eggs, fruits, and legumes, seeds and nuts, while consumption of other vegetables did not differ between the patterns. The third pattern was named “Rice, noodles and pork” (31% of population) because individuals in this pattern had high probabilities of consuming rice and rice products as well as instant noodles, bread and tubers. Moreover, they had high probabilities of intake of non-ruminant red meat (mainly pork), condiments and spices, and eggs. Total energy intake was highest in this pattern (1,858 kcal/d). In general, all three patterns had similar and balanced macronutrient intakes (60% carbohydrates; 20% fats) (Supplementary materials, Table S2.7).

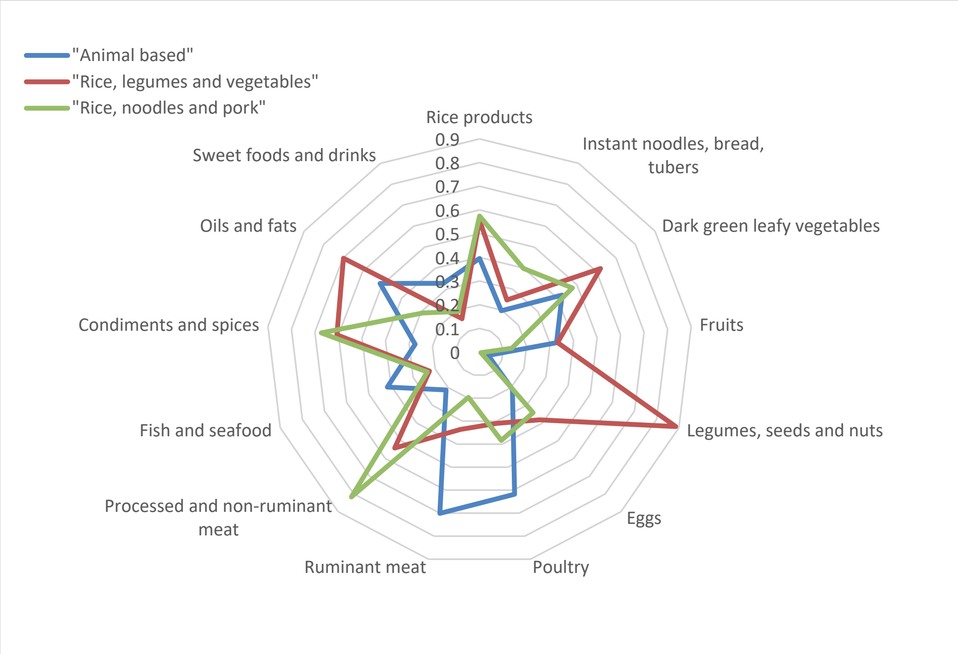

Figure 2.1 Proportion of the population in the highest category of intake per food groups, for each latent dietary pattern, Vietnam.

For Nigeria, we also identified three dietary patterns (Supplementary materials Table S2.9). The first pattern was named “High intakes and vegetables” (39% of population) as individuals in this pattern had high probabilities of consumption of most food groups, especially grains, dark green leafy vegetables and other vegetables, fish and seafood, legumes, condiments and spices, and oils and fats, (Figure 2.2, Supplementary material Tables S10-S11). Consistently, total energy intake was highest in this pattern (2737 kcal/d), with a relatively high intake of fat (Supplementary materials Table S2.11). The second pattern was named “Low intakes” (36% of population) because individuals in this pattern had low intakes of most food groups. This pattern was mainly characterized by intake of white roots and tubers, dark green leafy vegetables and grains, and had lowest energy intakes (2,010 kcal/d). The third pattern was named “Dairy and sugar” (25% of population) because individuals in this pattern had high probabilities of intakes of dairy, sweets (baked and other), and sweet tea, coffee, and cocoa. Additionally, they had higher intakes of red meat than the other patterns, and lower intakes of fish and seafood and white roots and tubers.

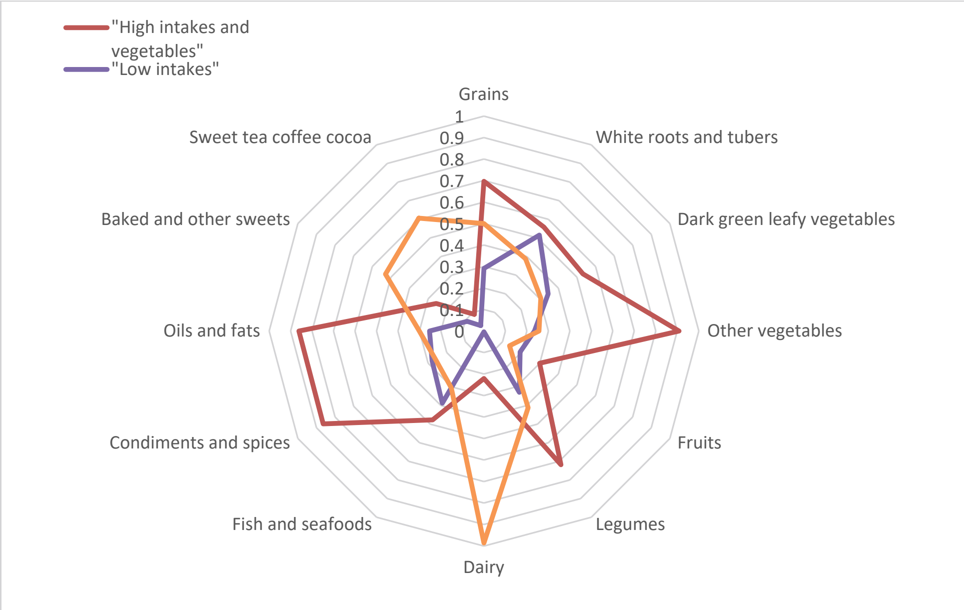

Figure 2.2 Proportion of the population in the highest category of intake per food groups, for each latent dietary pattern, Nigeria.

Diet quality of dietary patterns

The overall study population in Vietnam had a mean FGDS of 4.7 (SD 0.9) (Table 2.3). Mean GDQS was 20 (±4), with a GDQS Healthy score of 8 (±4) and GDQS Unhealthy score of 12 (±0.8). Mean MPA was 0.40 (± 0.2). FGDS, GDQS, GDQS Healthy and GDQS risk differed significantly between all dietary patterns, whereas GDQS Unhealthy and MPA were similar across all patterns. Individuals in the “Rice, legumes and vegetables” pattern had the overall healthiest diet, with the majority of the individuals having the highest FGDS (5±0.8), and the highest GDQS (23±3) and GDQS Healthy (11±3). They had higher intake of folate (PA 0.4), probably due to the higher intake of vegetables, especially dark green leafy vegetables. Individuals in the “Rice, noodles and pork” pattern had the lowest dietary quality, with the lowest FGDS (4±0.8), and the lowest GDQS Healthy score (7±3) but not higher consumption of unhealthy foods. Individuals in the “Animal based” dietary pattern had a medium adequacy and quality, with a FGDS of 5 (±0.8), a GDQS score of 20 (±3) and GDQS Healthy score of 8 (±3). They had lower intake of thiamin (PA 0.2) and vitamin B6 (PA 0.7). Individuals of all patterns had high adequacy of vitamin B12 (ranging from 0.82 to 0.99), probably due to the overall high consumption of meat, but a low adequacy of calcium (PA 0.0), likely due to low consumption of dairy products.

In Nigeria, the overall study population had a mean FGDS of 4 (SD ±1) (Table 2.4). Mean GDQS was 19 (±4), with a GDQS Healthy score of 9 (±4) and GDQS Unhealthy score of 10 (±2), and mean MPA was 0.63 (±0.2). We found statistically significant associations between dietary patterns and all diet quality indicators. Individuals in the "High intakes and vegetables" pattern had the overall healthiest diet, with the highest FGDS (5±0.8), GDQS (20±4), GDQS Healthy score (10±3) and MPA (0.75±0.2). Individuals in the "Low intakes" pattern had the least diverse and adequate diet. The individuals in this cluster had a FGDS of 4 (± 1), a low score for GDQS Healthy (8±4) and high score for GDQS Unhealthy (10±1), and they had the lowest MPA (0.50±0.2). Diets of individuals in the "Dairy and sugar" pattern had the lowest GDQS score (18±4), because of their low intake of healthy foods (GDQS Healthy of 8±3) and high intake of unhealthy foods (GDQS Unhealthy 10±2). Mean FGDS of individuals in this pattern was 4 (±1) and their MPA was 0.61 (±0.3).

Characterization of consumers of dietary patterns

Vietnamese individuals in the "Animal based" dietary pattern were generally living in the peri-urban areas (72%) (Table 2.1). Individuals in this pattern had the highest educational level compared to other dietary patterns (67% above secondary education), generally conducted skilled labor (53%), and in contrast had a lower living standard index (40% in lowest tertile). They experienced the least food insecurity (1.3%), although food insecurity did not statistically significantly differ between patterns. Compared to the other patterns, individuals with the "Rice, legumes and vegetables" pattern were slightly older (mean age 42 years), mostly in the medium living standard tertile (35%) and had primary education or below as highest educational level (22%). Individuals in the "Rice, noodles and pork" pattern were more often single than those in other patterns (8%,) and from slightly larger households (average of 5 people) compared to the other patterns. In addition, more individuals had no formal education (8%), conducted more unskilled work (49%) or were unemployed (12%), and in contrast were more in the high living standard tertile (41%) compared to the other patterns.

In Nigeria, none of the general characteristics was statistically significantly different over the three identified dietary patterns (Table 2.2). More individuals with the "High intakes and vegetables" pattern were single conducted unskilled labor, lived in the peri-urban area, had a higher education and were less food insecure compared to the other patterns. Individuals in the "Low intakes" pattern included more unemployed individuals; whereas individuals in the "Dairy and sugar" pattern were generally females, married, conducted skilled labor, had a lower living standard index, and experienced more food insecurity compared to the other patterns.

Table 2.3 Dietary quality indicators of the total population and stratified by dietary pattern. Vietnam.

	Total population	**"Animal based"**	**"Rice, legumes and vegetables"**	**"Rice, noodles and pork"**	**P-value [1]**
n	385	149	116	120	
FGDS, mean ±SD	4.7 ± 0.9	4.5 ± 0.8[a]	5.3 ± 0.8[b]	4.3 ± 0.8[c]	**<0.001**
GDQS, mean ±SD	20.1 ± 3.7	19.9 ± 3.3[a]	22.5 ± 3.1[b]	18.2 ± 3.3[c]	**<0.001**
GDQS healthy, mean ±SD	8.4 ± 3.6	8.1 ± 3.2[a]	10.8 ± 3.2[b]	6.5 ± 3.1[c]	**<0.001**
GDQS unhealthy, mean ±SD	11.7 ± 0.8	11.8 ± 0.8	11.7 ± 0.8	11.7 ± 0.9	0.51
GDQS risk, %					**<0.001**
Low	24.7	18.1[a]	50.9[b]	7.5[c]	
Moderate	68.3	76.5	47.4	78.3	
High	7.0	5.4	1.7	14.2	
MPA, mean ±SD	0.40 ± 0.24	0.38 ± 0.23	0.41 ± 0.25	0.41 ± 0.22	0.48
PA nutrients, median [IQR]					
Calcium	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.01]	0.00 [0.00, 0.00]	
Zinc	0.57 [0.09, 1.00]	0.52 [0.06, 1.00]	0.67 [0.13, 1.00]	0.62 [0.15, 1.00]	
Thiamin	0.64 [0.02, 1.00]	0.23 [0.00, 0.97]	0.75 [0.05, 1.00]	0.99 [0.33, 1.00]	
Riboflavin	0.00 [0.00, 0.02]	0.00 [0.00, 0.01]	0.00 [0.00, 0.01]	0.00 [0.00, 0.05]	
Vitamin B6	0.84 [0.15, 1.00]	0.71 [0.09, 1.00]	0.93 [0.08, 1.00]	0.90 [0.39, 1.00]	
Vitamin B12	0.97 [0.02, 1.00]	0.97 [0.03, 1.00]	0.82 [0.00, 1.00]	0.99 [0.08, 1.00]	
Vitamin C	0.08 [0.00, 0.99]	0.34 [0.00, 1.00]	0.08 [0.00, 1.00]	0.00 [0.00, 0.50]	
Folate	0.24 [0.01, 0.90]	0.29 [0.01, 0.85]	0.37 [0.04, 0.98]	0.12 [0.00, 0.77]	
Niacin	0.87 [0.32, 1.00]	0.80 [0.24, 1.00]	0.88 [0.34, 1.00]	0.92 [0.48, 1.00]	
Vitamin A	0.04 [0.00, 0.61]	0.02 [0.00, 0.65]	0.05 [0.00, 0.61]	0.05 [0.00, 0.57]	
Iron	0.00 [0.00, 0.15]	0.00 [0.00, 0.07]	0.00 [0.00, 0.17]	0.00 [0.00, 0.07]	

[1] p-value of test of bivariate associations between dietary patterns and diet quality indicators, using bias-adjusted three-step approach in LatentGold software.

[a,b,c] different superscripts indicate a p<0.05 for pairwise difference; for categorical variables the superscript refers to all categories. p-values are reported in Supplementary material s Table S2.8. FGDS = Food Group Diversity Score; GDQS = General Diet Quality Score; MPA= Mean probability of nutrient adequacy, calculated as an average of the PA of each individual. Possible ranges indicators: FGDS: 0-10, GDQS: 0-49, GDQS-Healthy: 0-32, GDQS-Unhealthy: 0-17, GDQS risk: Low: GDQS ≥23, Medium: ≤ 15 GDQS > 23, High: GDQS < 15, MPA and PA: 0-1.

Table 2.4 - Dietary quality indicators of the total population and stratified by dietary pattern. Nigeria.

	Total population	High intakes and vegetables	Low intakes	Dairy and sugar	p-value[1]
n	344	134	124	86	
FGDS, mean ±SD	4.4 ± 1.0	4.8 ± 0.8[a]	4.1 ± 1.0[b]	4.4 ± 1.1[c]	**<0.001**
GDQS, mean ±SD	18.9 ± 3.7	19.9 ± 3.6[a]	18.5 ± 3.7[b]	18.1 ± 3.5[ab]	**<0.001**
GDQS healthy, mean ±SD	9.0 ± 3.5	10.1 ± 3.3[a]	8.3 ± 3.5[b]	8.4 ± 3.3[ab]	**<0.001**
GDQS unhealthy, mean ±SD	9.9 ± 1.5	9.9 ± 1.5[a]	10.3 ± 1.4[ab]	9.6 ± 1.6[ac]	**0.01**
GDQS risk, %					**<0.001**
Low	13.4 (46)	18.7[a]	9.7[b]	10.5[b]	
Moderate	70.9 (244)	73.1	70.2	68.6	
High	15.7 (54)	8.2	20.2	20.9	
MPA, mean ±SD	0.63 ± 0.24	0.75 ± 0.17[a]	0.50 ± 0.24[b]	0.61 ± 0.25[c]	**<0.001**
PA nutrients, median [IQR]					
Calcium	0.19 [0.00, 0.98]	0.69 [0.03, 1.00]	0.00 [0.00, 0.26]	0.39 [0.01, 1.00]	
Zinc	0.43 [0.02, 1.00]	0.94 [0.27, 1.00]	0.04 [0.00, 0.64]	0.51 [0.05, 0.99]	
Thiamin	1.00 [0.46, 1.00]	1.00 [0.99, 1.00]	0.53 [0.01, 1.00]	1.00 [0.82, 1.00]	
Riboflavin	0.40 [0.00, 1.00]	0.98 [0.20, 1.00]	0.03 [0.00, 0.69]	0.26 [0.00, 1.00]	
Vitamin B6	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [0.91, 1.00]	1.00 [0.75, 1.00]	
Vitamin B12	1.00 [0.18, 1.00]	1.00 [0.39, 1.00]	1.00 [0.03, 1.00]	1.00 [0.17, 1.00]	
Vitamin C	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [0.99, 1.00]	1.00 [0.87, 1.00]	
Folate	1.00 [0.42, 1.00]	1.00 [0.98, 1.00]	0.66 [0.05, 1.00]	0.99 [0.32, 1.00]	
Niacin	1.00 [0.63, 1.00]	1.00 [0.94, 1.00]	0.87 [0.10, 1.00]	1.00 [0.48, 1.00]	
Vitamin A	0.12 [0.00, 1.00]	0.25 [0.01, 1.00]	0.04 [0.00, 0.90]	0.10 [0.00, 0.99]	
Iron	0.25 [0.04, 0.75]	0.30 [0.04, 0.82]	0.25 [0.04, 0.65]	0.25 [0.00, 0.65]	

[1] p-value of test of bivariate associations between dietary patterns and diet quality indicators, using bias-adjusted three-step approach in LatentGold software.

[a,b,c] different superscripts indicate a p<0.05 for pairwise difference; for categorical variables the superscript refers to all categories. p-values are reported in Supplementary materials Table S2.12. FGDS = Food Group Diversity Score; GDQS = General Diet Quality Score; MPA= Mean probability of nutrient adequacy, calculated as an average of the PA of each individual. Possible ranges indicators: FGDS: 0-10, GDQS: 0-49, GDQS-Healthy: 0-32, GDQS-Unhealthy: 0-17, GDQS risk: Low: GDQS ≥23, Medium: ≤ 15 GDQS > 23, High: GDQS < 15, MPA and PA: 0-1.

DISCUSSION

This study identified three dietary patterns in each country, named “Animal based”, “Rice, legumes and vegetables” and “Rice, noodles and pork” in Vietnam; and “High intakes and vegetables”, “Low intakes”, and “Dairy and sugar” in Nigeria. Diet quality differed between the patterns identified, with highest quality in Vietnam for individuals adhering to the “Rice, legumes and vegetables” diet and lowest diet quality for individuals adhering to the “Rice, noodles and pork” diet; and in Nigeria the highest diet quality for individuals adhering to the “High intakes and vegetables” diet and lowest for the “Low intakes” diet. Age, household size, number of children, area of residence, marital status, living standard index, education, and occupation were associated with the Vietnamese dietary patterns, whereas none of the sociodemographic variables were associated with dietary patterns in Nigeria.

Efforts to improve diet quality have focused on the identification of vulnerable groups and treating them as if they are all homogeneous in terms of nutritional needs. Populations have been targeted based on general indicators such as geographic areas (urban versus rural), sex, or socioeconomic status. However, nutritional differences occur within these subpopulations and therefore it is relevant to segment consumers based on their dietary patterns to develop tailored interventions. The importance of looking into segments of the population based on dietary intakes is highlighted in our analysis with the identification of unique dietary patterns differing in diet quality. Additionally, in Vietnam we were able to characterize the consumers of these patterns and identify the sociodemographic variables associated with the different patterns. By contrast, in Nigeria, we did not find associations between sociodemographic characteristics and dietary patterns. Therefore, it might be more insightful to investigate the consumer segment rather than defining them by, for instance, geographic area as consumers differ also within the same area of residences.

In both countries, we found that dietary patterns characterized by higher vegetable consumption were the healthiest in terms of nutrient adequacy and lower risk of non-communicable diseases. Dietary patterns with higher intakes of fruits and vegetables and greater diversity have been previously described in the Nigerian context (44) and were associated with lower risk of double burden of malnutrition (45). Therefore, increasing fruit and vegetable consumption in existing dietary patterns could be one of the main focus points to improve diet quality.

Moreover, we found that individuals in all patterns consumed foods from unhealthy food groups. Intervening on consumer choices and food environment to reduce consumption of and access to unhealthy foods may be beneficial for all consumers of our study populations both in the Vietnamese and Nigerian contexts. In Vietnam, the dietary pattern with high processed and red meat consumption had a low diet quality and higher risk of non-communicable diseases, based on GDQS. Previous studies reported meat consumption as typical of the Vietnamese diet since the last decades of economic growth (46–48). In Nigeria, consumption of unhealthy foods was mainly in terms of sweetened food (baked sweets, sugared tea, coffee, and cocoa). Comparable to our findings, high consumption of sweet snacks was reported in dietary patterns of school-aged children living in Ibadan (49), and of the general population that is shifting away from the "traditional" diet (50). These foods are commonly consumed, but increase the risk of obesity and non-communicable diseases (51). Higher consumption of snacks was associated with food insecurity in other studies (45,52). In line, experienced food insecurity tended to be highest in consumers of the pattern containing most sweetened foods in our study population. All in all, strategies aiming to reduce consumption of unhealthy foods may focus on specific food groups depending on the country and target specific segment of population, as found in our Vietnamese population.

The dietary pattern with the lowest diet quality in Vietnam was the "rice, noodles and pork" pattern, characterized by highly available and cheap food groups (53,54). This may reflect that healthy diets are unaffordable for urban poor (2), as consumers of this dietary pattern were mainly living in urban areas, single, part of a larger household, and unskilled employed or unemployed (52). These are all factors that may negatively affect their purchase power, regardless of the selection of an overall study population with a low-income. On the other hand, the "animal based" pattern that was characterized by high intakes of ruminant meat and lower intakes of grains, occurred more in the peri-urban areas, suggesting that these individuals have more purchase power compared to the urban group, despite their similar income. In other studies conducted in the Vietnamese context it was reported that income and education were associated with higher meat consumption and lower staple consumption, regardless of area of residence (urban or rural) (46,53,55).

As expected, the "low intakes" dietary pattern found in the Nigerian population had the lowest quality of the diet reflected in the lowest nutrient adequacy, which increases the risk of micronutrient deficiencies (45). Although the three identified dietary patterns in Nigeria differed in quality and suggest that consumers make different food choices and have different dietary habits, none of the sociodemographic variables differed between patterns. This is in contrast to a previous study in Nigeria in which it was reported that wealthier households living in urban areas had higher intakes of refined carbohydrate (50). A potential explanation for the lack of association in the current study is the homogeneity of the study population in terms of sociodemographic characteristics as all respondents came from a low-income neighborhood. Another explanation might be that the food intake of our Nigerian study population is not driven by personal characteristics and motives but rather by their external food environment. This includes for instance different price and quality ranges within the same market, time available for shopping or cooking, distance to work and being exposed to a different food environments (6), which we could not capture by the single indicator of area of residence used in this study. A study conducted in Ibadan found that food choices of individuals who work for long hours highly depend on the food offered around the workplace, such as street foods characterized by high energy and low vegetable content (56). Thus, further research in a more heterogenous study population and including external indicators that affect consumption is needed to better characterize Nigerian consumers.

This study has several strengths. First, the selection of both males and females from low-income households, which are most at risk for nutritional inadequacies and thus of importance to target with nutritional interventions, allowed us to have a comprehensive overview of the target population. Second, dietary intake data was collected using two quantitative 24hRs, which carefully estimates portion sizes. Third, we examined associations with a wide range of possible predictors of dietary patterns. Fourth, the inclusion of two countries allowed us to investigate two different contexts, and indeed results were different. We also have to acknowledge certain limitations of our study. Dietary data was collected in one month only and does not capture seasonality and habitual intakes. Especially consumption of seasonal food groups, such as fruit and vegetable, could vary during the year (57). In addition, our findings cannot be generalized to the overall population as we focused on low-income urban adults. Moreover, our sample size was relatively small, as LCA analysis requires around 500 individuals as a rule of thumb, so that we may have failed to identify dietary patterns. Nevertheless, we performed a range of sensitivity analyses to test the robustness of our results. For example, we compared models including dietary intakes as continuous variables and as categorical variables, and the categorization of intakes showed the best model fit. Moreover, in the Vietnamese data, we split the food groups into subgroups for meat and starchy foods in accordance with local dietary habits. The dietary patterns that emerged were largely similar using different sublevels of food groups, leaving us confident that the identified dietary patterns in these study populations are robust.

Overall, in both countries we found substantial groups of individuals consuming different food patterns, suggesting that in low-income urban and peri-urban populations in Hanoi, Vietnam, and Ibadan, Nigeria, consumers make different food choices. Diet quality differed between patterns suggesting that different needs coexist in the same context. Combining dietary pattern analysis with consumer characteristics can help to identify target populations for specific nutrition interventions.

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SUPPLEMENTARY MATERIALS

Table S2.1 Food Group Diversity Score (FGDS) food groups

	Food group	Score
1	Grains, white roots and tubers, and plantains	0/1
2	Pulses (beans, peas and lentils)	0/1
3	Nuts and seeds	0/1
4	Dairy	0/1
5	Meat, poultry and fish	0/1
6	Eggs	0/1
7	Dark green leafy vegetables	0/1
8	Other vitamin A-rich fruits and vegetables	0/1
9	Other vegetables	0/1
10	Other fruits	0/1

Table S2.2 Global Dietary Quality Score (GDQS) Healthy and Unhealthy food groups and scoring adapted from (29)

		Categories of Consumed Amounts (g/d)				Score Points			
Score	**Food groups**	**Low**	**Middle**	**High**	**Very high**	**Low**	**Middle**	**High**	**Very high**
GDQS Healthy	Citrus fruits	<24	24-69	>69		0	1	2	
	Deep orange fruits	<25	25-123	>123		0	1	2	
	Other fruits	<27	27-107	>107		0	1	2	
	Dark green leafy vegetables	<13	13-37	>37		0	2	4	
	Cruciferous vegetables	<13	13-36	>36		0	0.25	0.5	
	Deep orange vegetables	<9	9-45	>45		0	0.25	0.5	
	Other vegetables	<23	23-114	>114		0	0.25	0.5	
	Legumes	<9	9-42	>42		0	2	4	
	Deep orange tubers	<12	12-63	>63		0	0.25	0.5	
	Nuts and seeds	<7	7-13	>13		0	2	4	
	Whole grains	<8	8-13	>13		0	1	2	
	Liquid oils	<2	2-7.5	>7.5		0	1	2	
	Fish and shellfish	<14	14-71	>71		0	1	2	
	Poultry and game meat	<16	16-44	>44		0	1	2	
	Low-fat dairy	<33	33-132	>132		0	1	2	
	Eggs	<6	6-32	>32		0	1	2	
GDQS Unhealthy	High-fat dairy	<35	35-142	>142-734	>734	0	1	2	0
	Red meat	<9	9-46	>46		0	1	0	
	Processed meat	<9	9-30	>30		2	1	0	
	Refined grains and backed foods	<7	7-33	>33		2	1	0	
	Sweets and ice-cream	<13	13-37	>37		2	1	0	
	Sugar-sweetened beverages	<57	57-180	>180		2	1	0	
	Juice	<36	36-144	>144		2	1	0	
	White roots and tubers	<27	27-107	>107		2	1	0	
	Purchased deep fried foods	<9	9-45	>45		2	1	0	

Table S2.3 Food groups categorization and percentage of non-consumers for Vietnam

	Non-consumers, n	Non-consumers, %	Categorization (number of categories)
Rice and rice noodles	0	0	Median split (2)
Bread, instant noodles and tubers	174	45.1	Non-consumers+median (3)
Other vegetables	18	4.7	Median split (2)
Dark green leafy vegetables	20	5.4	Median split (2)
Fruits	177	46	Non-consumers+median (3)
Legumes nuts and seeds	159	41	Non-consumers+median (3)
Eggs	150	39.2	Non-consumers+median (3)
Poultry	214	55.2	Yes/no (2)
Processed and non-ruminant meat	36	9.4	Median split (2)
Ruminant meat	219	56.9	Yes/no (2)
Fish	152	39.2	Non-consumers+median (3)
Dairy	375	96.6	Yes/no (2)
Sweet foods and drinks	295	77	Yes/no (2)
Condiments and spices	0	0.0	Median split (2)
Oils and other fats	30	7.7	Median split (2)
Deep fried snacks	359	93.3	Yes/no (2)

Table S2.4 Food groups categorization and percentage of non-consumers for Nigeria

	Non- consumers, n	Non-consumers, %	Categorization, (number of categories)
Grains	5	1.4	Median split (2)
White roots and tubers	35	9.6	Median split (2)
Fruits	268	77.9	Yes/no (2)
Dark green leafy vegetables	68	18.7	Non-consumers+median (3)
Other vegetables	1	0.3	Median split (2)
Legumes	22	6.0	Median split (2)
Nuts and seeds	198	54.4	Yes/no (2)
Eggs	176	48.4	Non-consumers+median (3)
Poultry	328	90.1	Yes/no (2)
Red meat	150	41.2	Non-consumers+median (3)
Fish	73	20.1	Non-consumers+median (3)
Dairy	240	65.9	Yes/no (2)
Instant noodles	336	92.3	Yes/no (2)
Baked and other sweets	162	47.1	Non-consumers+median (3)
Sweetened beverages	230	63.2	Yes/no (3)
Sweetened tea and coffee	276	80	Yes/no (3)
Condiments and spices	0	0.0	Median split (1)
Oils and other fats	1	0.3	Median split (1)
Deep fried snacks	320	87.9	Yes/no (3)
Alcohol	329	95.6	Yes/no (3)

Latent class model fit Vietnam

In the model for Vietnam, BIC was lowest for the 2-class model while AIC and AIC3 showed an elbow at 3 classes (Table S2.5). The entropy R^2 for 2 classes was very low (.49) but adequate for 3 classes (.72), and the classification error was lowest in the 3-class model. Moreover, the interpretation of the 3-class model was more useful, thus we selected the 3 class model. There was an indication of a multilevel effect of households, and the 3-Cluster 3-GClass model seemed to provide the best fit (Model 10). We explored higher level clustering of individuals based on households. Following the recommendations by Lukociene et al (57) we did a sequential process of class selection, namely first selecting the number of lower level classes, followed by a selection of the higher level classes while keeping the number of lower level classes fixed. The large majority of individuals (above 90%) in any of the three clusters belonged to the same GClass, indicating that the multilevel effect of household was small and therefore we continued with the 3-Cluster 1-GClass model. In the final model (Model 15), we excluded deep fried foods, other and vitamin A rich vegetables, and dairy as indicators, because of their low contribution to the classification. Allowing for correlation between food groups with high BVR did not further improve the model fit and the final maximum BVR was 11.2.

Table S2.5 Model fit statistics of Latent Class Analysis for identification of dietary patterns, Vietnam

		LL	BIC(LL)	AIC(LL)	AIC3(LL)	Npar	L^2	df	p-value	Max. BVR	Class.Err.	Entropy R^2
Model1	1-Cluster	-4569,45	9263,91	9180,89	9201,89	21	4604,8	364	1,3e-72	22,407	0	1
Model2	2-Cluster	-4518,03	9262,29	9112,06	9150,06	38	4501,973	347	1,9e-71	22,089	0,1562	0,4863
Model3 – selected model	3-Cluster	-4471,52	9270,48	9053,05	9108,05	55	4408,959	330	2,7e-70	11,549	0,118	0,7219
Model4	4-Cluster	-4438,4	9305,42	9020,79	9092,79	72	4342,701	313	1,3e-69	16,909	0,1122	0,7616
Model5	5-Cluster	-4412,64	9355,11	9003,27	9092,27	89	4291,185	296	5,2e-69	10,18	0,1581	0,7118
Model6	6-Cluster	-4389,88	9410,81	8991,77	9097,77	106	4245,677	279	9,1e-70	10,612	0,1501	0,748
Model7	7-Cluster	-4366	9464,24	8977,99	9100,99	123	4197,902	262	3,3e-70	4,615	0,1565	0,77
Model8	3-Cluster 1-GClass	-4471,52	9270,48	9053,05	9108,05	55				11,549	0,118	0,7219
Model9	3-Cluster 2-GClass	-4421,19	9187,68	8958,39	9016,39	58				11,778	0,0737	0,802
Model13 – model 3 wo deep fried food	3-Cluster	-4376,37	9062,30	8856,73	8908,73	52	4218,642	333	1,9e-66	11,485	0,1183	0,7212
Model14 – model 13 wo other and vitamin A rich vegetables	3-Cluster	-4109,65	8511,01	8317,29	8366,29	49	3693,523	336	2,1e-56	11,402	0,1179	0,7212
Model15 – model 14 wo dairy	3-Cluster	-4057,75	8389,35	8207,50	8253,50	46	3592,504	339	6,1e-54	11,166	0,1225	0,7064

3-Cluster model was selected as best model. Model 15 was model fit after excluding non-significant food groups (deep fried food; other and vitamin A rich vegetables; and dairy), and was the final model. Allowing for correlation between pairs of food groups with high BVR values did not improve the model fit.

Table S2.6 Probabilities of consumption for selected food items by dietary patterns derived by LCA, Vietnam

	"Animal based"	"Rice, legumes and vegetables"	"Rice, noodles and pork"
Cluster Size	38%	31%	31%
Indicators			
Rice and rice products			
below median	0.60	0.44	0.42
above median	0.40	0.56	0.57
Dark green leafy vegetables			
below median	0.58	0.38	0.52
above median	0.42	0.62	0.48
Condiments and spices			
below median	0.72	0.39	0.33
above median	0.27	0.61	0.67
Oils and fats			
below median	0.49	0.30	0.71
above median	0.51	0.70	0.29
Instant noodles, bread and tubers			
non consumers	0.54	0.48	0.32
below median	0.26	0.28	0.28
above median	0.20	0.25	0.40
Eggs			
non consumers	0.50	0.30	0.34
below median	0.30	0.31	0.31
above median	0.21	0.38	0.34
Fish and seafood			
non consumers	0.27	0.47	0.46
below median	0.31	0.30	0.30
above median	0.42	0.22	0.24
Poultry			
non consumers	0.38	0.69	0.62
consumers	0.62	0.31	0.38
Fruits			
non consumers	0.389	0.38	0.63
below median	0.28	0.28	0.24
above median	0.33	0.33	0.14
Legumes, nuts and seeds			
non consumers	0.48	0.00	0.75
below median	0.48	0.11	0.24
above median	0.04	0.88	0.01
Sweet foods and drinks			
non consumers	0.67	0.84	0.81
consumers	0.33	0.16	0.19
Processed and non-ruminant meat			
below median	0.79	0.46	0.18
above median	0.21	0.54	0.82
Ruminant meat			
non consumers	0.30	0.66	0.80
consumers	0.70	0.34	0.20

Table S2.7 Intake of each food group of the total population and stratified by dietary pattern, Vietnam

	Total population	"Animal based"	"Rice, legumes and vegetables"	"Rice, noodles and pork"
	Median [IQR]	**Median [IQR]**	**Median [IQR]**	**Median [IQR]**
n	385	149	116	120
Rice and rice products	301.0 [235.0, 390.4]	280.3 [203.2, 371.7]	317.2 [267.2, 397.5]	322.5 [249.6, 399.2]
Instant noodles, bread, and tubers	4.2 [0.0, 16.1]	0.0 [0.0, 11.3]	0.5 [0.0, 14.5]	10.7 [0.0, 18.9]
Instant noodles	0.0 [0.0, 10.7]	0.0 [0.0, 5.2]	0.0 [0.0, 10.7]	0.0 [0.0, 16.1]
Bread	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
White roots and tubers	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Condiments and spices	13.6 [9.0, 23.2]	10.1 [6.6, 14.6]	17.0 [10.2, 26.9]	17.6 [11.4, 26.9]
Oils and other fats	4.9 [1.9, 8.8]	4.9 [1.6, 8.0]	7.7 [4.6, 11.5]	2.4 [1.1, 5.3]
Legumes, nuts and seeds	7.3 [0.0, 38.9]	2.1 [0.0, 15.2]	55.4 [42.9, 77.5]	0.0 [0.0, 0.2]
Legumes	3.6 [0.0, 38.9]	0.0 [0.0, 14.3]	55.4 [42.5, 77.1]	0.0 [0.0, 0.0]
Nuts and seeds	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Dark green leafy vegetables	30.9 [15.1, 52.0]	26.3 [9.1, 44.8]	39.4 [19.7, 67.3]	30.1 [15.5, 51.6]
Other vegetables[1]	36.6 [14.7, 67.3]	35.5 [12.6, 64.4]	41.0 [22.7, 65.3]	36.4 [12.4, 72.2]
Vitamin A-rich orange vegetables	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Other vegetables	35.5 [13.7, 64.7]	34.6 [12.4, 63.5]	36.6 [21.2, 63.0]	35.1 [9.9, 69.7]
Fruit	4.5 [0.0, 33.5]	11.7 [0.0, 36.0]	12.0 [0.0, 45.7]	0.0 [0.0, 8.4]
Citrus	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.7]	0.0 [0.0, 0.0]
Vitamin A rich fruits	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Other fruits	0.0 [0.0, 19.0]	0.0 [0.0, 24.8]	0.1 [0.0, 25.6]	0.0 [0.0, 0.0]
Unprocessed ruminant meat	0.0 [0.0, 11.3]	7.9 [0.0, 16.9]	0.0 [0.0, 6.6]	0.0 [0.0, 0.0]
Processed and non-ruminant meat	31.9 [13.9, 63.4]	16.0 [3.9, 27.0]	34.2 [16.9, 71.4]	59.5 [42.1, 86.1]
Unprocessed non ruminant meat	30.2 [12.5, 63.4]	14.3 [2.9, 26.1]	33.6 [15.6, 71.4]	58.4 [39.6, 86.1]
Processed meat	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Poultry	0.0 [0.0, 28.1]	7.1 [0.0, 36.0]	0.0 [0.0, 8.0]	0.0 [0.0, 27.1]
Fish and seafood	2.9 [0.0, 10.7]	6.2 [0.0, 17.5]	0.1 [0.0, 8.2]	0.8 [0.0, 6.2]
Eggs	7.4 [0.0, 16.0]	2.0 [0.0, 12.2]	9.0 [0.0, 16.4]	8.6 [0.0, 24.0]
Dairy[1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Deep fried foods[1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Sweet foods and drinks	0.0 [0.0, 0.0]	0.0 [0.0, 0.1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Baked and other sweets	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Sweetened beverages	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Sweet tea, coffee, cocoa [2]	-	-	-	-
Alcoholic beverages [2]	-	-	-	-

Table S2.7 (Continued)

Energy, kcal	1714 [1444, 2008]	1542 [1334, 1800]	1813[1603, 2175]	1858 [1532, 2134]
Carbohydrates, % energy	59.6 [52.4, 64.7]	60.0 [52.4, 64.3]	58.1 [51.7, 63.9]	60.9 [53.0, 66.0]
Carbohydrates, g	248.1 [207.5, 302.0]	223.7 [185.1, 263.6]	257.7 [224.4, 302.7]	268.2 [219.8, 329.3]
Fat, % energy	21.8 [17.5, 26.7]	21.1 [16.7, 25.5]	22.9 [18.5, 28.6]	22.1 [17.4, 27.2]
Fat, g	41.2 [30.3, 55.2]	36.9 [27.5, 46.8]	44.1 [34.4, 60.5]	44.5 [31.7, 60.0]
Protein, g	76.6 [64.2, 90.2]	73.7 [62.2, 85.1]	83.4 [69.4, 99.7]	78.3 [63.5, 90.4]
Fibre, g	6.4 [4.9, 8.4]	7.0 [5.3, 9.1]	7.2 [5.2, 9.0]	5.8 [4.5, 7.0]

[1] Food group excluded from the model because not contributing to the determination of dietary patterns

[2] <5% of consumers of this food group

Table S2.8 Paired comparisons of associations between variables and dietary patterns in Vietnam[1]

Variables	"Animal based" versus "Rice, legumes and vegetables"	"Animal based" versus "Rice, noodles and pork"	"Rice, legumes and vegetables" versus "Rice, noodles and pork"
	Wald (p-value)	Wald (p-value)	Wald (p-value)
General characteristics			
Age	9.58 (0.002)	0.01 (0.92)	8.9 (0.003)
Females	1.67 (0.20)	2.19 (0.14)	0.11 (0.74)
BMI [2]	0.45 (0.50)	0.75 (0.39)	2.33 (0.13)
Peri-urban	27.3 (<0.001)	46.5 (<0.001)	11.6 (<0.001)
Household size	0.06 (0.80)	5.7 (0.02)	5.7 (0.02)
Number of children	21.3 (<0.001)	7.5 (0.006)	0.49 (0.48)
Marital status	23.3 (<0.001)	14.5 (<0.001)	2.78 (0.25)
Living standard	1.75 (0.19)	9.19 (0.002)	4.06 (0.04)
Education	14.7 (<0.001)	20.6 (<0.001)	1.35 (0.24)
Occupation	6.95 (0.07)	12.0 (0.007)	7.15 (0.07)
Experienced food insecurity	1.80 (0.18)	1.86 (0.17)	0.01 (0.91)
Diet quality indicators			
FGDS	46.89 (<0.001)	12.8 (<0.001)	110.8 (<0.001)
GDQS	41.0 (<0.001)	22.1 (<0.001)	127.6 (<0.001)
GDQS healthy	43.2 (<0.001)	21.3 (<0.001)	130.5 (<0.001)
GDQS unhealthy	0.50 (0.48)	1.28 (0.26)	0.21 (0.64)
GDQS risk	29.6 (<0.001)	7.6 (0.006)	39.9 (<0.001)
MPA	1.38 (0.24)	0.71 (0.40)	0.11 (0.74)

[1] Wald statistics of Chi squared tests comparing variables across each pair of dietary patterns, to test for which pairs the variables are significantly different.

[2] BMI available for n=384

Latent class model fit Nigeria

In the model for Nigeria, BIC was lowest for the 3 class model while AIC and AIC3 showed also a clear elbow at 3 classes, and the entropy R^2 of the model was acceptable (.74) (Table S8). There was no multilevel effect of households, and therefore the 1-GClass model was selected (Model 8-12, Table 3). In the final model (model 23), we excluded instant noodles, poultry, deep fried foods, red meat, sweetened beverages, eggs, alcohol, and nuts and seeds as indicators, because of their low contribution to the classification. We allowed for correlation between dark green leafy vegetables * roots and tubers, fish and seafood * dark green leafy vegetables, and fish and seafood * condiments and spices, foods often consumed in mixed dishes, which resulted in an acceptable maximum BVR of 4.6.

Table S2.9 Model fit statistics of Latent Class Analysis for identification of dietary patterns. Nigeria.

		LL	BIC(LL)	AIC(LL)	AIC3(LL)	Npar	L²	df	p-value	Max. BVR	Class. Err.	Entropy R²
Model1	1-Cluster	-4679,44	9504,902	9408,89	9433,886	25	5348,843	319	2,4e-900	114,06	0	1
Model2	2-Cluster	-4539,98	9348,625	9171,95	9217,955	46	5069,912	298	3,1e-856	106,2815	0,0782	0,7219
Model3 – Selected model	3-Cluster	-4461,84	9315,012	9057,69	9124,689	67	4913,645	277	2,8e-837	36,2361	0,0887	0,7945
Model4	4-Cluster	-4424,83	9363,632	9025,66	9113,656	88	4839,612	256	2,4e-835	14,491	0,113	0,7974
Model5	5-Cluster	-4390,82	9418,263	8999,63	9108,633	109	4771,589	235	6,5e-835	14,322	0,1398	0,7752
Model6	6-Cluster	-4360,51	9480,296	8981,01	9111,012	130	4710,968	214	2,7e-836	8,9744	0,1328	0,7916
Model7	7-Cluster	-4339,21	9560,356	8980,42	9131,419	151	4668,375	193	8,8e-842	11,783	0,1366	0,8016
Model8	3-Cluster 1-GClass	-4461,84	9315,012	9057,69	9124,689	67				36,236	0,0887	0,7945
Model9	3-Cluster 2-GClass	-4455,62	9320,095	9051,25	9121,25	70				38,552	0,0763	0,8228
Model 13 – model 3 excluding instant noodles	3-Cluster	-4367,53	9108,863	8863,06	8927,062	64	4725,018	280	8,3e-797	36,099	0,0881	0,7952
Model 14 – model 13 excluding poultry	3-Cluster	-4259,13	8874,529	8640,25	8701,25	61	4508,207	283	9,4e-751	36,189	0,0858	0,8001
Model 15 – model 14 excluding deep fried food	3-Cluster	-4132,31	8603,384	8380,63	8438,627	58	4257,356	286	5,2e-698	35,894	0,0866	0,7979
Model 16 – model 15 excluding red meat	3-Cluster	-3759,93	7835,246	7627,85	7681,851	54	3526,443	290	1,0e-548	35,748	0,0863	0,799
Model 17 – model 16 sweet beverages	3-Cluster	-3535,11	7368,089	7172,22	7223,216	51	3091,717	293	5,3e-461	35,693	0,0873	0,7968
Model 18 – model 17 eggs	3-Cluster	-3175,56	6625,634	6445,12	6492,124	47	2395,853	297	3,6e-324	35,269	0,0883	0,7946
Model 19 – model 18 excluding alcohol	3-Cluster	-3115,89	6488,764	6319,78	6363,776	44	2279,277	300	1,00E-300	35,399	0,0878	0,7959
Model 20 – model 19 excluding nuts and seeds	3-Cluster	-2881,38	6002,235	5844,77	5885,768	41	1859,635	303	1,40E-221	35,425	0,0881	0,7916

Table 2.9 Continued

Model 21 – model 20 + direct effect tubers*leaf veg	3-Cluster	-2859,9	5965,104	5803,79	5845,797	42	1816,663	302	3,80E-214	22,802	0,0888	0,7986
Model 22 – model 21 + direct effect fish*leaf veg	3-Cluster	-2846,41	5943,974	5778,83	5821,826	43	1789,693	301	1,20E-209	9,7025	0,0857	0,8043
Model 23 – model 22 + final model: direct effect fish*condiments	3-Cluster	-2837,37	5931,729	5762,74	5806,741	44	1771,607	300	9,00E-207	4,5559	0,0822	0,807
Model 24 – model 23 + direct effect grains*legumes	3-Cluster	-2834,27	5931,363	5758,53	5803,534	45	1765,401	299	4,90E-206	4,4021	0,0823	0,805

Table S2.10. Probabilities of consumption for selected food items by dietary patterns derived by LCA, Nigeria

	"High intakes and vegetables"	"Low intakes"	"Dairy and sugar"
Cluster Size	39%	36%	25%
Indicators			
Baked and other sweets			
Non-consumers	0.45	0.69	0.19
Below median	0.30	0.22	0.28
Above median	0.26	0.09	0.53
Vitamin A rich fruits and other fruits			
Non-consumers	0.70	0.81	0.86
Consumers	0.30	0.19	0.14
Grains			
Below median	0.30	0.71	0.50
Above median	0.70	0.29	0.50
White roots and tubers			
Below median	0.44	0.48	0.61
Above median	0.56	0.52	0.39
Other vegetables			
Below median	0.09	0.76	0.74
Above median	0.91	0.24	0.26
Legumes			
Below median	0.28	0.67	0.59
Above median	0.72	0.33	0.41
Condiments and spices			
Below median	0.14	0.72	0.74
Above median	0.86	0.28	0.26
Oils and fats			
Below median	0.14	0.75	0.70
Above median	0.86	0.25	0.30
Dairy			
Non-consumers	0.78	0.99	0.01
Consumers	0.22	0.00	0.98
Sweet tea coffee cocoa			
Non-consumers	0.91	0.97	0.39
Consumers	0.09	0.03	0.61
Dark green leafy vegetables			
Non-consumers	0.10	0.22	0.26
Below median	0.36	0.43	0.44
Above median	0.53	0.34	0.30
Fish and seafood			
Non-consumers	0.14	0.21	0.28
Below median	0.38	0.40	0.41
Above median	0.48	0.39	0.30

Full conditional distribution of food groups consumption for each latent dietary pattern.

Table S2.11. Intake of each food group of the total population and stratified by dietary pattern, Nigeria.

	Total population	High intakes and vegetables	Low intakes	Grains and sugar
	Median [IQR]	Median [IQR]	Median [IQR]	Median [IQR]
n	344	134	124	86
Grains (rice and bread)	146.2 [80.1, 228.1]	191.2 [128.9, 297.3]	97.8 [50.6, 155.7]	147.3 [86.5, 233.0]
Instant noodles[1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
White roots and tubers	59.6 [25.2, 124.7]	77.2 [28.8, 129.0]	62.8 [26.6, 127.8]	48.6 [18.2, 102.3]
Condiments and spices	108.6 [58.0, 173.7]	178.3 [125.6, 245.3]	75.0 [47.2, 108.7]	66.8 [42.3, 114.2]
Oils and other fats	67.7 [40.9, 119.2]	126.4 [84.2, 191.8]	50.9 [29.7, 67.2]	47.9 [26.7, 74.1]
Legumes	18.4 [6.7, 44.7]	38.4 [15.0, 68.6]	12.2 [3.7, 23.4]	13.3 [4.3, 33.0]
Nuts and seeds[1]	0.0 [0.0, 1.9]	0.1 [0.0, 3.2]	0.0 [0.0, 1.0]	0.0 [0.0, 1.9]
Dark green leafy vegetables	12.4 [2.4, 27.0]	19.9 [9.2, 36.9]	8.0 [1.8, 22.3]	5.6 [0.0, 18.2]
Vita A rich orange vegetables	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Other vegetables	215.1 [115.2, 342.3]	367.6 [271.8, 500.7]	147.0 [91.4, 195.9]	131.5 [63.1, 215.6]
Fruits	0.0 [0.0, 0.0]	0.0 [0.0, 16.1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Citrus	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Vitamin A rich fruits	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Other fruits	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Red meat[1]	5.2 [0.0, 24.5]	3.6 [0.0, 26.6]	4.7 [0.0, 20.7]	11.3 [0.0, 26.4]
Unprocessed ruminant meat	4.5 [0.0, 23.4]	0.6 [0.0, 24.5]	4.6 [0.0, 19.1]	10.6 [0.0, 23.5]
Unprocessed non ruminant meat	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Processed meat	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Poultry[1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Fish and seafood	17.1 [3.0, 57.8]	26.6 [5.6, 80.5]	15.4 [2.8, 47.8]	8.9 [0.0, 44.8]
Eggs[1]	0.4 [0.0, 13.4]	1.0 [0.0, 15.6]	0.0 [0.0, 13.4]	2.2 [0.0, 13.3]
Dairy	0.0 [0.0, 1.7]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	5.3 [2.4, 16.9]
Baked and other sweets	0.5 [0.0, 4.7]	0.6 [0.0, 4.5]	0.0 [0.0, 0.6]	4.1 [0.9, 9.7]
Baked sweets	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Other sweets	0.0 [0.0, 3.6]	0.0 [0.0, 3.0]	0.0 [0.0, 0.1]	2.4 [0.6, 8.3]
Deep fried foods[1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Sweetened beverages[1]	0.0 [0.0, 50.0]	0.0 [0.0, 35.7]	0.0 [0.0, 50.0]	0.0 [0.0, 74.1]
Sweet tea, coffee or cocoa	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	2.9 [0.0, 7.0]

Table 2.11 Continued

Alcoholic beverages[1]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]
Energy, kcal	2399 [1882, 3021]	2737 [2234, 3342]	2010 [1557, 2580]	2376 [1927, 2995]
Carbohydrates, % energy	59.6 [53.8, 66.3]	56.8 [52.5, 62.3]	62.7 [55.8, 68.8]	61.8 [55.3, 66.7]
Carbohydrates, g	360.8 [266.6, 449.6]	395.7 [315.2, 490.4]	314.5 [233.1, 400.3]	373.9 [268.5, 460.4]
Fat, % energy	26.3 [20.7, 32.5]	29.2 [24.5, 34.0]	22.7 [18.3, 31.2]	24.1 [19.9, 30.7]
Fat, g	70.0 [48.4, 91.1]	88.2 [71.2, 109.9]	53.1 [40.2, 71.3]	63.6 [45.4, 86.5]
Protein, g	65.1 [48.6, 87.2]	77.0 [58.0, 99.9]	53.0 [39.0, 78.4]	63.5 [50.0, 89.0]
Fibre, g	21.8 [14.7, 29.7]	24.4 [19.4, 32.1]	17.5 [12.7, 28.1]	20.3 [15.2, 26.5]

[1] Food group excluded from the model because not contributing to the determination of dietary patterns

Table S2.12 Paired comparisons of associations between variables and dietary patterns in Nigeria[1]

Variables	**"High intakes and vegetables" versus "Low intakes"**	**"High intakes and vegetables" versus "Dairy and sugar"**	**"Low intakes" versus "Dairy and sugar"**
	Wald (p-value)	Wald (p-value)	Wald (p-value)
General characteristics			
Age	1.27 (0.26)	1.46 (0.23)	0.01 (0.94)
Females	0.14 (0.71)	2.97 (0.09)	2.09 (0.15)
BMI[2]	0.28 (0.60)	3.25 (0.07)	1.99 (0.16)
Peri-urban	1.68 (0.19)	1.83 (0.18)	0.02 (0.89)
Household size	0.47 (0.49)	0.48 (0.49)	1.8 (0.17)
Number of children [3]	0.21 (0.65)	0.44 (0.51)	0.05 (0.82)
Marital status	1.28 (0.73)	1.83 (0.61)	0.39 (0.94)
Living standard	0.0002 (0.99)	2.08 (0.15)	2.3 (0.13)
Education	2.06 (0.15)	1.73 (0.19)	0.004 (0.95)
Occupation	5.92 (0.12)	2.00 (0.57)	2.57 (0.46)
Experienced food insecurity	0.27 (0.60)	3.72 (0.05)	2.15 (0.14)
Diet quality indicators			
FGDS	52.2 (<0.001)	12.9 (<0.001)	6.3 (0.01)
GDQS	14.2 (0.001)	20.7 (<0.001)	0.72 (0.40)
GDQS healthy	23.5 (<0.001)	18.4 (<0.001)	0.20 (0.66)
GDQS unhealthy	3.6 (0.06)	1.24 (0.27)	7.8 (0.005)
GDQS risk	11.5 (<0.001)	10.2 (0.001)	0.03 (0.86)
MPA	111.9 (<0.001)	30.9 (<0.001)	12.4 (<0.001)

[1] Wald statistics of Chi squared tests comparing variables across each pair of dietary patterns, to test for which pairs the variables are significantly different.

[2] Number of children available for n=276

[3] BMI available for n=332

Chapter 3

A simple fruit and vegetable score is a valid tool to assess actual fruit and vegetable intake

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ABSTRACT

Background With the recent growing interest in improving fruit and vegetable intake for better health and limited research resources in many settings, simple-to-administer and low-priced indicators are essential tools for monitoring fruit and vegetable intake at the population level. A potential candidate indicator is the fruit and vegetable component of the Global Dietary Recommendations score (FV-GDR) based on data collected using the Diet Quality Questionnaire (DQQ).

Objective To investigate the relative validity of the FV-GDR collected with the DQQ to measure the actual intake of fruit and vegetable at the population level.

Methods We compared the FV-GDR of the DQQ to the results of a quantitative 24-hour recall (24hR), as a reference, collected from 620 Vietnamese and 630 Nigerian adults in 2021.

Results We found proportional differences in the prevalence of intake of vitamin A-rich vegetables, other vegetables, and other fruits in Vietnam, and all vegetable food groups in Nigeria. In both countries, we found a small difference in the total FV-GDR from DQQ compared to the 24hR, and the percentage of agreement between the two methods was quite high for the majority of the food groups. The FV-GDR calculated from the DQQ correlated with the actual intake, although less strongly than the FV-GDR from 24hR.

Conclusions The DQQ is a promising low-burden, low cost and simple tool to calculate FV-GDR and to monitor fruit and vegetable consumption at the population level. This provides the possibility of evaluating an important aspect of diet quality in low-resource settings.

INTRODUCTION

Suboptimal diets characterized by low fruit and vegetable (FV) consumption are highly prevalent, especially in South Asia and Africa (1,2). Assessing diet quality at the population level can help monitor and evaluate potential public health risk factors (3). Simple to-administer and low-priced indicators are essential tools to facilitate this and to overcome budget and resource limitations faced in many local and research settings (4). At present, the majority of commonly used diet quality indicators are based on resource-intensive methodologies using quantitative data, such as weighted food records and quantitative 24-hour recalls (24hR) (5). These dietary assessment methods require highly skilled interviewers and burdensome and time-consuming data collection processes (6). Therefore, the use of these indicators is not always feasible in poor-resource settings, and intuitive, simple, and low-burden indicators that reflect adequate intake are needed.

To address this gap, tools to collect population-level consumption data of food groups have been developed, such as a list-based or recall tool on the consumption of ten food groups to calculate the Food Group Dietary Diversity Score (FGDS). The FGDS is the sum of the number of food groups consumed, and a score ≥5, referred to as the minimum dietary diversity score for women (MDD-W) (7), is related to adequate micronutrient intake in women of reproductive age (8,9). The FGDS includes three FV food groups: 1) dark green leafy vegetables, 2) other vitamin A-rich fruits and vegetables, and 3) other vegetables. It is commonly used in settings where quantitative data collection is not possible (10). However, the FGDS does not provide information on the risk of diet-related non-communicable diseases and has not been validated for men (11). The recently developed Diet Quality Questionnaire (DQQ) (12) is a simple and intuitive questionnaire, which enables gathering information on the consumption of 29 food groups. In addition to calculating the FGDS, the DQQ can also be used to estimate the Global Dietary Recommendations (GDR) (4). The GDR score reflects adherence to global recommendations and the risk of non-communicable diseases and is based on the consumption of seventeen food groups, including six FV food groups (the FV component): 1) vitamin A-rich vegetables, 2) dark green leafy vegetables, 3) other vegetables, 4) vitamin A-rich fruits, 5) citrus, and 6) other fruits.

With the recent growing interest in improving FV intake for better health and sustainability (13,14), we hypothesised that the FV component of the GDR score (FV-GDR) can also be used to monitor and evaluate FV intake at the population level. This would provide a simple tool, requiring low training time and capability of the enumerators and simple processing of the data. To the best of our knowledge, only two studies have examined the validity of such a simple score to evaluate FV consumption. Herforth et al. showed good agreement between the FV-GDR and meeting the international FV recommendations of 400 g/d when derived from the same datasets (4), but Hanley-Cook et al. showed low agreement in the proportion of women consuming FV of the FDGS compared to a weighed food record (15).

In this paper, we investigate the relative validity of the FV-GDR collected with the DQQ to measure the actual intake of FV at the population level. We compared the FV-GDR of the DQQ to the results of a quantitative 24hR (as reference method) collected among a Vietnamese and a Nigerian study population to answer the following questions: 1) Do the two methods similarly estimate the proportion of food groups consumed at the population level? 2) Are FV intakes similarly correlated with FV-GDR irrespective whether the score is calculated from DQQ or from the reference method (24hR)?

METHOD

Study area and population

This study uses data collected as part of the 'Fruit and Vegetable intake in Vietnam and Nigeria' research project (FVN), which aimed to increase FV consumption of a low-income Vietnamese and Nigerian urban population. The FVN project focusing on women and men of reproductive age (19-49) at the start, covered a total of two years. For the current study we used FVN endline data, hence including 620 Vietnamese and 630 Nigerian women and men of 21-51 years of age. For each respondent, two dietary assessments were collected with at least two days in between each interview. In Vietnam (1240 observations) data were collected from October to December 2021 in Hanoi from two urban areas (Dong Da and Nam Tu Liem) and two peri-urban areas (Ha Dong and Thanh Tri). In Nigeria (1247 observations) data were collected in Ibadan from November to December 2021 from two urban areas (Abaeja and Apete) and two peri-urban areas (Bagadaje and Ariyibi).

Ethical approval

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Hanoi Medical University Institutional Review Board in Hanoi (45-18/HMU-IRB) and the University of Ibadan/University College Hospital Ethical Review Committee (UI/UCH-ERC) in Nigeria (HNHREC/05/01/2008a). Written informed consent was obtained from all subjects.

Dietary assessments

Dietary intake was assessed using a Dietary Quality Questionnaire (DQQ) (16) and the multi-pass quantitative 24-hour recall (24hR) method (17,18). The DQQ was collected digitally with KoboToolbox software (19), while 24hRs were collected on paper. Both dietary assessments were carried out during the same interview, always administering the DQQ first, followed by the 24hR, and in duplicate on a non-consecutive day. Trained local interviewers conducted interviews during home visits.

Dietary Quality Questionnaire

The DQQ includes 29 dichotomous questions (yes/no) about the food items and drinks consumed on the previous day or night, from when the respondent woke up the previous day to when she/he woke up on the day of the interview (12). Each question includes a list of sentinel country-specific food items that reflects commonly consumed foods. These were identified from previous dietary assessments and key informant interviews with the local experts. Therefore, the specific sentinel food items included in the questionnaire differed between the two countries. For the present study, we considered only six questions regarding FV: 1) pro-vitamin A-rich orange vegetables; 2) dark green leafy vegetables; 3) other vegetables; 4) pro-vitamin A-rich fruits; 5) citrus; and 6) other fruits (Supplementary material, Tables S3.1-S3.2). Pro-vitamin A-rich orange vegetables and fruits are further referred to as 'vitamin A-rich vegetables' and 'vitamin A-rich fruits' for consistency with other publications on DQQ and GDR (4,16,20).

Quantitative 24hour Recall

We used the multi-pass quantitative 24hR method (17,18) as a reference method for the validation of the DQQ. During home visits, respondents were asked, in the presence of the person who prepared the food, to recall all the foods and beverages they had consumed in and outside their home from waking up the day before the interview until waking up the day of the interview. Respondents were asked to describe in detail the composition of the mixed dishes, types of ingredients, and cooking methods. To estimate the amount consumed, foods or ingredients still present in the household were weighed directly using an electronic kitchen scale (LP-B series for Vietnam; Camry EK5055 for Nigeria) with a precision of one decimal. If foods were unavailable, equivalent volumes of water or dry foods, such as rice or flour, or monetary values were used to estimate the amount consumed of each ingredient (18). Then, the total volume of the cooked dish, the portion served, and the portion left over were estimated using water. To calculate the actual intake in grams, waste factors, conversion factors, and standardized recipes were applied.

Variables construction

FV food group consumption was defined as the consumption of each of the six FV food groups based on the GDR score. For each individual and recall day, a binary score for each food group consumed was extracted from the DQQ, and constructed from the 24hR, being 1 if consumed and 0 if not consumed. For 24hR, all the consumed FV food items were aggregated into the same six food groups. Only foods consumed in quantities of at least 15 g were considered for comparison with the DQQ, as the DQQ focuses on sentinel (commonly consumed) FV, assuming the exclusion of food items consumed in small amounts (21). The total FV-GDR score was defined as the sum of each FV food group consumed, ranging from 0 to 6, and was calculated based on the DQQ and 24hR. The total FV (grams per day) consumed was calculated from 24hR, summing the quantities of each FV item consumed.

Data analysis

All analyses were conducted separately for Vietnam and Nigeria, and each dietary assessment for each respondent was considered a separate observation (descriptive analyses of single recall days are reported in Supplementary materials, Tables S3.3-S3.4). The difference in the population prevalence of each FV food group between DQQ and 24hR was calculated by subtracting the 24hR value from the DQQ value and was tested with linear mixed model to account for dependent observations. The difference in the mean total FV-GDR score between the DQQ and 24hR was calculated by subtracting the value of the 24hR value from the DQQ value and was tested with Wilcoxon rank test. To measure agreement between DQQ and 24hR two-by-two tables were constructed. The proportion of misreporting in each FV group was calculated by investigating type I, false positive (FP), and type II, false negative (FN), errors. The FP and FN values were used to calculate the sensitivity and specificity of the consumption of each food group. Furthermore, we used linear mixed models to investigate the correlation of individual food groups among methods, total FV-GDR score, with actual FV intake from both DQQ and 24hR. We hypothesized that higher FV-GDR scores corresponded to higher FV intake using both methods. We tested for differences in the correlation coefficients between the two methods using Zou's method (22) and Hittner's method (23) as implemented in the R package cocor (24) for dependent correlations with overlapping variables. Data analysis was performed in R (25), and a significance level of $p < 0.05$ and a difference in proportion >10% were considered meaningful (26,27).

RESULTS

General population characteristics

More than half of the study population were women (65% in Vietnam and 66% in Nigeria) (Supplementary materials Table S3.5). The mean ±SD age of the total population was 38 ± 7 years in Vietnam and 37 ± 8 years in Nigeria and the majority of respondents completed secondary education and above (41% in Vietnam and 31% in Nigeria). In Vietnam, 27% of respondents were formally employed, more than a quarter was informally employed, and 8% owned a business. In Nigeria, a large proportion of the respondents were formally (42%) or informally employed (38%).

Differences between DQQ and 24hR

In Vietnam, the median (interquartile range (IQR)) of FV-GDR based on DQQ (2 (1), range 0–5) was lower than that based on the 24hR (3 (1), range 1–5) ($p < 0.001$) (Figure 3.1a), mainly due to underreporting of the consumption of 'other vegetables' (20 percentage points) and 'other fruits' (18 percentage points) (Table 3.1). These were the only two food groups with a difference in proportion of >10%. In Nigeria, the median (IQR) FV-GDR based on DQQ (3 (2), range 0-6) was higher than that of the 24hR (2 (1), range 0-6) ($p < 0.001$) (Figure 3.1b), mainly due to the overreporting of 'vitamin A-rich vegetables' (41 percentage points) (Table 3.1). Histogram of the FV-GDR distribution (Figure S3.1) and results from the sensitivity analysis for differences in proportion between methods including only the sentinel foods of the DQQ (Table S3.6) and all quantities consumed (Table S3.7) can be found in the Supplementary materials.

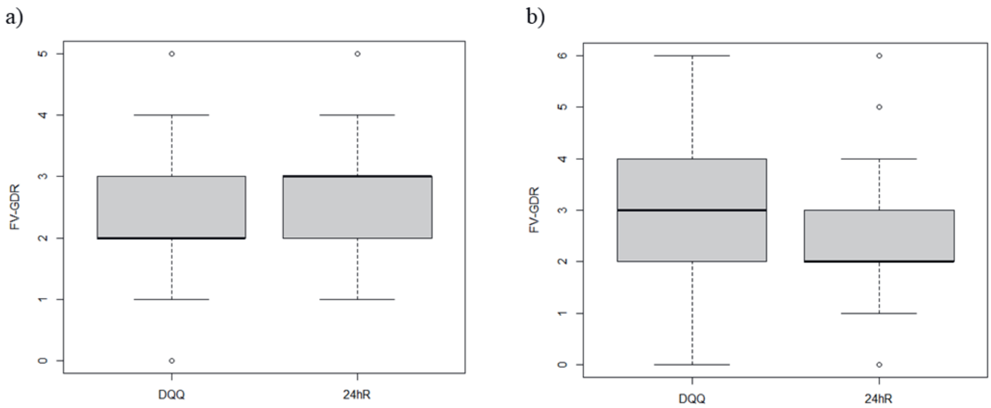

Figure 3.1 Box-and-whisker plots showing FV-GDR of the a) Vietnamese and b) Nigerian population as calculated from DQQ and 24hR, respectively. The bottom and top edge of the box represent the first and third quartiles (interquartile range); the bold line within the box represents the median; and the ends of the bottom and top whiskers represent the 10th and 90th percentiles, respectively.

Table 3.1 Proportions of Vietnamese and Nigerian populations having consumed each fruit and vegetable food group from DQQ and 24hR, and median intake based on 24hR

	Vietnam					**Nigeria**				
	DQQ (n=1240)		**24hR (n=1240)**			**DQQ (n=1247)**		**24hR (n=1247)**		
	n	**%**	**n**	**%**	**Median intake, g (IQR)**	**n**	**%**	**n**	**%**	**Median intake, g (IQR)**
Vitamin A-rich vegetables	167	13.5***	121	9.8	0 (0)	638	51.2***	125	10	0 (0)
Dark green leafy vegetables	1013	81.7	991	79.9	109.6 (145)	822	65.9***	702	56.3	21 (48)
Other vegetables	748	60.3***	989	79.8	124.6 (207)	1137	91.2***	1187	95.2	89.2 (102)
Vitamin A-rich fruits	123	9.9	129	10.4	0 (0)	116	9.3	121	9.7	0 (0)
Citrus	388	31.3	373	30.1	0 (78)	396	31.8*	385	30.9	0 (140)
Other fruits	452	36.5***	681	54.9	52.8 (147)	338	27.1	345	27.7	0 (94)
Total	1236	99.7	122	98.9	409.5 (262)	1221	97.9	1224	98.2	263.7 (402)

DQQ = Dietary Quality Questionnaire; 24hR = 24hour recalls; n = number of observations; Median intake is reported in grams per day; IQR = interquartile range; *$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ for difference between DQQ and 24hR.

Agreement in food group consumption between DQQ and 24hR

In Vietnam, the per cent agreement coefficient of all food groups indicated high agreement between the DQQ and 24hR, ranging from 65% to 90% (Table 3.2). The DQQ correctly classified (e.g., true positive and true negative) ≥80% of respondents who consumed 'vitamin A-rich vegetables', 'dark green leafy vegetables', 'vitamin-A rich fruits', and 'citrus fruits', and >65% of respondents who consumed 'other vegetables' and 'other fruits'. Furthermore, DQQ had the highest sensitivity (e.g., true positive rate) for 'dark green leafy vegetables' (88%) and the highest specificity (e.g., true negative rate) for 'vitamin A-rich vegetables' and all fruit groups (82%-94%). In Nigeria, the per cent agreement coefficient of all fruit food groups indicated very good agreement (87%-98%), whereas a poorer agreement (56%) was found for 'vitamin A-rich vegetables' (Table 3.2). The DQQ correctly classified >85% of respondents as consuming all food groups, but only 56% of respondents consumed 'vitamin A-rich vegetables'. High sensitivity was found for all groups (88%-99%), and the specificity was higher for fruit groups (0.98-0.99) compared to the vegetable groups (0.53-0.74).

Misreporting of food groups by DQQ compared to 24hR

In Vietnam, type I measurement errors (FP) occurred mainly from the overreporting of 'dark green leafy vegetables' (11%) and 'citrus' (11%). Measurement error type II (FN) occurred from underreporting 27% of 'other vegetables' and 27% of 'other fruits' (Table 3.2). In Nigeria, type I errors mainly occurred from overreporting 42% of 'vitamin A-rich vegetables' and 11% of 'dark green leafy vegetables', whereas underreporting was low for all food groups (0.6%-1.8%) (Table 2).

Correlations of food groups and total score

In Vietnam, the correlations of food group consumption between the DQQ and 24hR ranged from 0.28 to 0.51 with $p < 0.001$ for all groups (Table 3.3). A $\beta_{st} = 0.38$ (95%CI 0.33, 0.43) was found between the total FV-GDR calculated from the 24hR and the total FV intake (Figure 3.2a). The correlation was lower between FV-GDR from the DQQ and total FV intake ($\beta_{st} = 0.21$, 95%CI 0.16, 0.27) (Figure 3.2b). Furthermore, the two correlations (DQQ vs. 24hR) were found to be different ($z = 5.59$, 95%CI 0.11-0.23). In Nigeria, a strong correlation between DQQ and 24hR was found for all fruit groups (0.92-0.95, $p < 0.001$) and 'dark green leafy vegetables' (0.71, $p < 0.001$) (Table 3.3). In contrast, $\beta_{st} = 0.24$ (95%CI 0.19, 0.30) was found for 'vitamin A-rich vegetables' and $\beta_{st} = 0.39$ (95%CI 0.34, 0.44) for 'other vegetables'. A high correlation was found between FV-GDR and total FV intake, but it was lower for the FV-GDR calculated from the DQQ ($\beta_{st} = 0.62$, 95%CI 0.58, 0.66) than for the 24hR ($\beta_{st} = 0.77$, 95%CI 0.73, 0.80) (Figure 3.3a-b). Also, for Nigeria, the two correlations (DQQ vs. 24hR) were found to be different ($z = 7.86$, 95%CI 0.11,0.19).

Table 3.2 Misreporting and agreement of food groups from DQQ and 24hR in the Vietnamese and Nigerian study population

	Misreporting				**Agreement statistics**
	% FP	**% FN**	**Sensitivity**	**Specificity**	**% agreement**
Vietnam					
Vitamin A-rich vegetables	8.5	4.8	0.5	0.90	90.2
Dark green leafy vegetables	11	9.3	0.88	0.45	79.7
Other vegetables	6.5	26	0.67	0.68	67.5
Vitamin A-rich fruits	5.2	5.7	0.45	0.94	89.0
Citrus	11	9.8	0.68	0.84	79.3
Other fruits	8.1	26.6	0.52	0.82	65.2
Nigeria					
Vitamin A-rich vegetables	42.3	1.2	0.88	0.53	56.4
Dark green leafy vegetables	11.2	1.6	0.97	0.74	87.2
Other vegetables	2	6	0.94	0.58	93.0
Vitamin A-rich fruits	0.5	0.9	0.91	0.99	98.6
Citrus	1.4	0.6	0.98	0.98	98.0
Other fruits	1.3	1.8	0.99	0.99	96.9

FP = False Positive, type I error; FN = False Negative, type II error. Coefficient agreement formula: ((a+d)/n)*100, a = number of observations not having consumed the food group in both DQQ and 24hR, d = number of observations having consumed the food group in both DQQ and 24hR, n = total number of observations.

Table 3.3 Associations between DQQ and 24hR per each food group for the Vietnamese and the Nigerian study population.

	Vietnam		**Nigeria**	
	β_{st}	**95%CI**	β_{st}	**95%CI**
Vitamin A-rich vegetables	0.33	0.28-0.38	0.24	0.19-0.30
Dark green leafy vegetables	0.34	0.29-0.40	0.71	0.71-0.78
Other vegetables	0.28	0.22-0.33	0.39	0.34-0.44
Vitamin A-rich fruits	0.40	0.35-0.45	0.92	0.90-0.94
Citrus	0.51	0.46-0.56	0.95	0.94-0.97
Other fruits	0.33	0.28-0.38	0.92	0.90-0.94

β_{st} = linear mixed model standardized estimates; for all correlations $p<0.001$

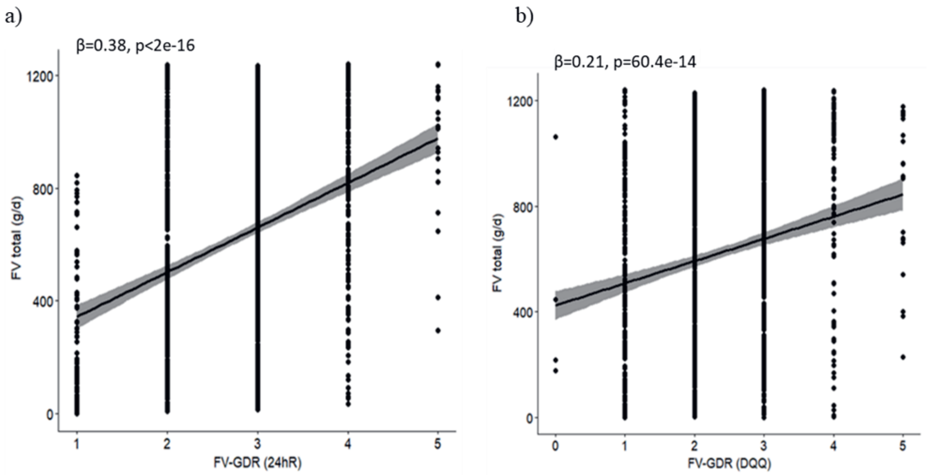

Figure 3.2 Regression of fruit and vegetable intake on FV-GDR score calculated from a) 24hR and b) DQQ for Vietnam. X-axis = fruit and vegetable component of the Global Dietary Recommendation score (FV-GDR); y-axis = fruit and vegetable (FV) intake in grams per day

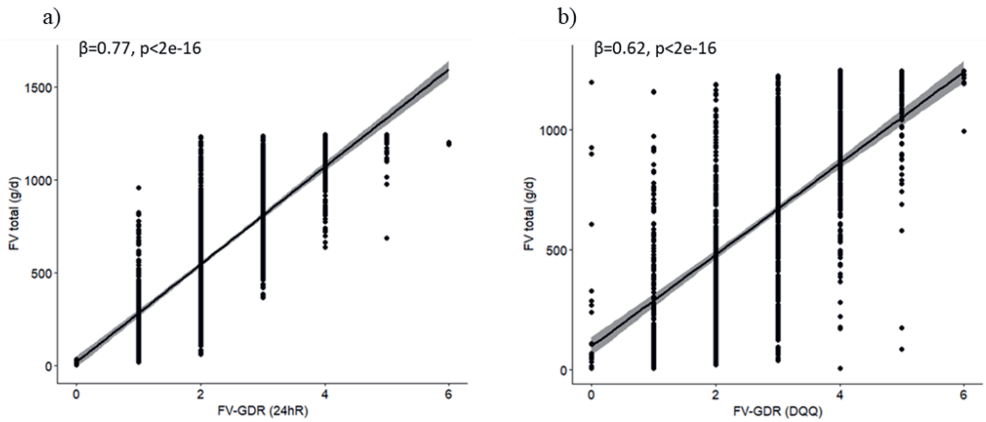

Figure 3.3 Regression of fruit and vegetable intake and FV-GDR score calculated from a) 24hR and b) DQQ for Nigeria. X-axis = fruit and vegetable component of the Global Dietary Recommendation score (FV-GDR); y-axis = fruit and vegetable (FV) intake in grams per day

DISCUSSION

In general, this study suggests that the fruit and vegetable component of the Global Dietary Recommendation score (FV-GDR) calculated from the Dietary Quality Questionnaire (DQQ) is a good indicator of FV intake at the population level. In two study countries, Vietnam and Nigeria, we found that the DQQ performs well in the estimation of consumption of total FV, with small differences in total FV-GDR compared to the reference method (24hR). The percentage of agreement in FV-GDR between the two methods was shown to be quite high for the majority of the FV food groups, and the FV-GDR from the DQQ correlated with the actual amount consumed, although less strongly than the FV-GDR calculated from the 24hR.

However, in both countries, the consumption of some specific food groups was underestimated ('other vegetables' and 'other fruits' in Vietnam) or overestimated ('vitamin A-rich vegetables' in Nigeria). Compared with the reference method, the DQQ seems to underestimate the intake of food groups that reflect a high variety of food items. For instance, the list of sentinel foods in the DQQ for 'other vegetables' did not capture some foods commonly consumed by the study population (bamboo shoots and mushrooms) or those consumed in specific seasons of the year (eggplants and kohlrabi). Moreover, the vegetables classified in the 'other vegetables' group consumed in mixed dishes or prepared out of home could have been underestimated with the DQQ because of the difficulty of recognizing, remembering, and measuring all ingredients (28), while being included as standard recipes in the processing of 24hR data. Moreover, as expected, the proportions of food group consumption became more similar when the proportion calculated from the 24hR was limited to the sentinel food items as included in the DQQ. Increasing the number of sentinel foods and the number of questions for food groups with a large variety may increase the probability of capturing the majority of food items consumed and reduce this underestimation. Furthermore, the lists of sentinel foods must be closely assessed to ensure that they fully capture the majority of food items available and actually consumed. Since the DQQ has been designed to assess the quality of diet at the country level, specific food habits of sub-populations may be missed. In our study, this issue may explain the underestimation of some food groups in Vietnam because the DQQ for the whole of Vietnam was used, but only a subpopulation from the city of Hanoi was assessed. In contrast, the Nigerian DQQ used in this study was tailored to the target population (FVN project). Therefore, the DQQs available from the Dietary Quality Project present slightly different lists of sentinel foods. Overall, adapting the questionnaire based on the context, sub-population targeted, specific region or period of the year of interest will increase the accuracy of estimation of intake using the DQQ.

In contrast, the DQQ seemed to overestimate food groups for which items were consumed in small portions. This could explain the large difference in the proportion of 'vitamin A-rich vegetables' consumed in Nigeria. This food group includes *tatashe*, one of the ingredients used to prepare a commonly consumed tomato-based sauce, which is consumed in small quantities. With the DQQ, respondents answered whether the listed foods were consumed, regardless of the quantity actually consumed. When we assessed the overestimation of 'vitamin-A rich vegetables' in the DQQ compared to 24hR without excluding foods consumed <15 g, the overestimation was indeed reduced. Additionally, the underreporting of the 24hR for episodically consumed foods, such as fruits, shown in studies in low-income countries, could also possibly explain the overestimation of the DQQ found in this study (29–32). In other words, respondents may have correctly reported their intake when probed by the DQQ list of sentinel foods, compared to the 24hR where they were prone to forget episodically consumed foods in an open recall.

Moreover, we found that the DQQ was more accurate in estimating fruit intake than vegetable intake. This is probably due to the modality of usual fruit consumption. We observed that fruits are commonly consumed per item and are rarely consumed in mixed dishes. Therefore, they are rarely consumed in amounts of <15 g, reducing the possibility of recall bias related to recalling several ingredients included in a dish. Second, because fruits are not commonly consumed, they are rarely consumed more than once a day or more than one type of fruit within the same food group (33), thus they are more easily remembered. This reduces the risk of underestimation and overestimation, although in contrast with Hanley-Cook's et al. findings (15). Third, especially in Nigeria, the varieties available and actually consumed are relatively low and, therefore, well represented in the DQQ sentinel food list. This may explain the high agreement in the consumption of all fruit food groups in this study in Nigeria. However, the high variety of fruits available and commonly consumed in Vietnam will increase the chance that some fruits are not captured in the DQQ, which could explain the lowest percentage of agreement for other fruit food groups found in our study in Vietnam. Therefore, including in the DQQ more questions for the food groups with a large variety of food items eaten, considering seasonal availability of items, and excluding from the list of sentinel foods, the items that are mainly consumed in low amounts (e.g., mixed in recipes, sauces) may contribute to addressing the above-mentioned causes of under- and over-estimation of some FV food groups.

Regarding the total FV-GDR, the DQQ seems to be a promising tool that can be used to evaluate and monitor FV intake at the population level. Although we found a statistically significant difference in the score between the two methods in our two study countries, we consider this difference not relevant at the population level and from a public health perspective. Considering that we propose the FV-GDR to assess and monitor FV intake in large populations, the evaluation of total FV intake would be similar between the two methods.

As hypothesized, FV-GDR positively correlated with the actual intake of FV in both methods. This correlation was stronger in Nigeria than in Vietnam. As expected, the correlation was lower when the FV-GDR was calculated from the DQQ, as it includes a limited list of food items compared to an open recall (34). However, the positive correlation indicates that a higher FV-GDR score based on the DQQ indicates a higher intake of FV, but does not indicate whether that intake is sufficient, i.e. meets the WHO recommendations of 400 g or more. At the individual level, Herforth et al. proposed a cut-off point for consuming at least three FV food groups, indicating adherence to the WHO recommendations (4). However, the proposed cut-off point has not been validated for any Asian or African country but was based on data from the United States and Brazil (4). Based on our data, there is a large difference (>20 percentage points) in the proportion of respondents above this cut-off point between the DQQ and 24hR, both in Vietnam and Nigeria, and we found a cut-off of 0.5 (Vietnam) and 1.5 (Nigeria). Although the identification of a global cut-off for FV food group intake would provide another useful indicator of adherence to diet quality recommendations, our data possibly suggests that optimal cut-off might vary across countries. Therefore, more research is needed to formulate such a global cut-off point.

The large number of observations and the administration of the two tools separately in the same interview allowed us to better estimate the validity of the FV component of the DQQ to assess FV actual intake at the population level (35). However, correlated measurement error might have inflated the correlation between the methods because both rely on the memory of the respondents. On the other hand, the correlated measurement error when investigating the correlation between intake (24hR) and score (DQQ) is lower than that obtained using the 24hR dataset for calculating the FV-GDR (35). Administration of the DQQ always before the 24hR prevented influencing the DQQ answers of the respondent through a 24hR, assuming that the DQQ would not affect the 24hR because it is a simpler method. In this study, we used 24hR as the reference method, although it is not the gold standard. Weighed food records could have provided a better estimation of the actual intake, but considering the budget and resources available for the study, 24hR was chosen as the best method (36). In addition, our results can be generalized only to low-income, mainly female populations in the context of urban and peri-urban Vietnam and Nigeria, and further investigation in other contexts (e.g., other countries, rural areas, and minorities with different habits) is needed to generalize the validity of the FV-GDR for monitoring FV intake at the population level.

To conclude, the DQQ is a very promising tool for calculating the FV-GDR and monitoring total FV consumption at the population level. It provides the possibility of using a low-burden, low-cost, and simple-to-use tool to assess FV intake in low-resource settings.

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SUPPLEMENTARY MATERIALS

Table S3.1 Fruit and vegetable questions of the Dietary Quality Questionnaire administrated in Vietnam

Do not read the food group names	**Yesterday did you eat any of the following vegetables?**	(circle answer)
Vitamin A rich orange vegetables	Carrot *(ca rot),* pumpkin *(bi ngo),* orange-fleshed sweet potato or purple-flesh sweet potato?	YES or NO
Dark green leafy vegetables	Morning glory/water spinach *(rau muong),* katuk *(rau ngót),* sweet potato leaves *(rau khoai lang)*, ceylon spinach (*rau mồng tơi*), pumpkin leaves (rau bí), chayote leaves (ngọn su su), or jute potherb (rau đay)?	YES or NO
Dark green leafy vegetables	Broccoli (Súp lơ xanh), amaranth *(rau den)*, watercress *(cai soong)*, napa cabbage *(cai thao)*, mustard greens *(cai xanh)*, cassava leaves, or crown daisy (cải cúc)?	YES or NO
Other vegetables	Cabbage *(cai bap)*, lettuce (rau xà lách), mung bean sprout, common bean (dau cove), cauliflower (sup lo trang), Pepper (ot chuong), or tomato (ca chua)?	YES or NO
Other vegetables	Calabash (bau), ashgourd/waxgourd (bi xanh), gourd (muop), bitter melon (muop dang), Cucumber (dua leo), White radish (cu cai trang), or chayote (su su)?	YES or NO
	Yesterday did you eat any of the following fruits?	(circle answer)
Vitamin A rich fruits	Ripe mango *(xoai chin)*, ripe papaya, passion fruit *(chanh leo)*, or persimmon *(hong mem)*?	YES or NO
Citrus	Orange *(cam)*, pomelo, grapefruit, tangerine, clementine, or mandarin?	YES or NO
Other fruits	Banana, pineapple (qua dua), avocado (qua bo), watermelon (dua hau), guava *(oi)*, grape (*nho ngot)*, or mangosteen (mang cut)?	YES or NO
Other fruits	Rambutan (chom chom), longan (nhan), litchi (qua vai), dragonfruit (thanh long), jackfruit (mit), durian (sau rieng), or sugar apple (na)?	YES or NO

Table S3.2 Fruit and vegetable questions of the Dietary Quality Questionnaire administrated in Nigeria

Do not read the food group names	**Yesterday did you eat any of the following vegetables?**	(circle answer)
Vitamin A rich orange vegetables	Carrot, pumpkin, tatashe, or orange or yellow-fleshed sweet potato?	YES or NO
Dark green leafy vegetables	Ewedu, amaranthus leaves, water leaf, shoko, bitter leaf, ugu, osun or spinach?	YES or NO
Other vegetables	Tomato, cucumber, okro or garden egg?	YES or NO
	Yesterday did you eat any of the following fruits?	(circle answer)
Vitamin A rich fruits	Ripe mango, ripe pawpaw, locust bean fruit, hog plum, or bush mango fruit?	YES or NO
Citrus	Orange, tangerine, tangelo or grapefruit?	YES or NO
Other fruits	Banana, agbalumo, watermelon, apple, avocado, coconut, pineapple, guava or cashew fruit?	YES or NO

Table S3.3 Proportions of food group consumed from DQQ and 24hR, and intakes from 24hR for recall 1 and recall 2, Vietnam

	Vietnam									
	Recall 1					Recall 2				
	DQQ (n=620)		24hR (n=620)			DQQ (n=620)		24hR (n=620)		
	n	**%**	**n**	**%**	**Median intake, g (IQR)**	**n**	**%**	**n**	**%**	**Median intake, g (IQR)**
Vitamin A-rich vegetables	86	13.9	71	11.5	0 (0)	81	13.1	81	13.1	0 (0)
Dark green leafy vegetables	512	82.6	500	80.6	118.5 (145)	501	80.8	497	80.2	100 (145)
Other vegetables	375	60.5	528	85.2	117.2 (208.3)	373	60.2	527	85	130.7 (205.3)
Vitamin A-rich fruits	55	8.9	61	9.8	0 (0)	68	11	68	11	0 (0)
Citrus	225	36.3	221	35.6	0 (97.3)	163	26.3	160	25.8	0 (40.7)
Other fruits	215	34.7	347	56	54.7 (148.5)	237	38.2	349	56.3	49.3 (146.8)
FV-GDR, mean (sd),	2.4	(0.9)	2.7	(0.8)		2.3	(0.9)	2.6	(0.8)	
Min-max	0	5	1	5		0	5	1	5	

DQQ **=** Dietary Quality Questionnaire; 24hR = 24hour recalls; n = number of observations; Median intake is reported in grams per day; IQR = interquartile range; *****$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ for difference between DQQ and 24hR.

Table S3.4 Proportions of food group consumed from DQQ and 24hR, and intakes from 24hR for recall 1 and recall 2, Nigeria

	Nigeria									
	Recall 1					**Recall 2**				
	DQQ (n=629)		**24hR (n=629)**			**DQQ (n=618)**		**24hR (n=618)**		
	n	**%**	**n**	**%**	**Median intake, g (IQR)**	**n**	**%**	**n**	**%**	**Median intake, g (IQR)**
Vitamin A-rich vegetables	317	50.4	68	10.8	0 (0)	321	51.9	57	9.2	0 (0)
Dark green leafy vegetables	438	69.6	370	58.7	23 (48)	384	62.1	332	53.8	19 (48)
Other vegetables	573	91.1	596	94.6	90.8 (114.6)	564	91.3	591	95.8	88 (90.5)
Vitamin A-rich fruits	51	8.1	55	8.7	0 (0)	65	10.5	66	10.7	0 (0)
Citrus	222	35.3	212	33.7	0 (170)	174	28.2	173	28	0 (140)
Other fruits	176	28	179	28.4	0 (94)	162	26.2	166	26.9	0 (94)
FV-GDR, mean (sd),	2.8	(1.2)	2.3	(1.1)		2.7	(1.2)	2.2	(1.1)	
Min-max	0	6	0	6		0	6	0	6	

DQQ = Dietary Quality Questionnaire; 24hR = 24hour recalls; n = number of observations; Median intake is reported in grams per day; IQR = interquartile range; *$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ for difference between DQQ and 24hR.

Table S3.5 General characteristics of the study population, Vietnam and Nigeria

	Vietnam	Nigeria
n	620	630
Age, mean years (sd)	38.4 (7.4)	37.3 (7.7)
Women, % (n)	64.9 (381)	65.9 (415)
Educational level, % (n)		
no education	0.5 (3)	4.3 (27)
primary school	4.1 (24)	21 (132)
secondary school	27.1 (105)	12.9 (81)
above secondary school	41 (241)	31.1 (196)
Occupation, % (n)		
Skilled employment	26.6 (156)	41.6 (262)
Unskilled employment	26.6 (156)	38.1 (240)
Own business	7.5 (64)	12.5 (79)
Unemployed	4 (24)	1.4 (9)

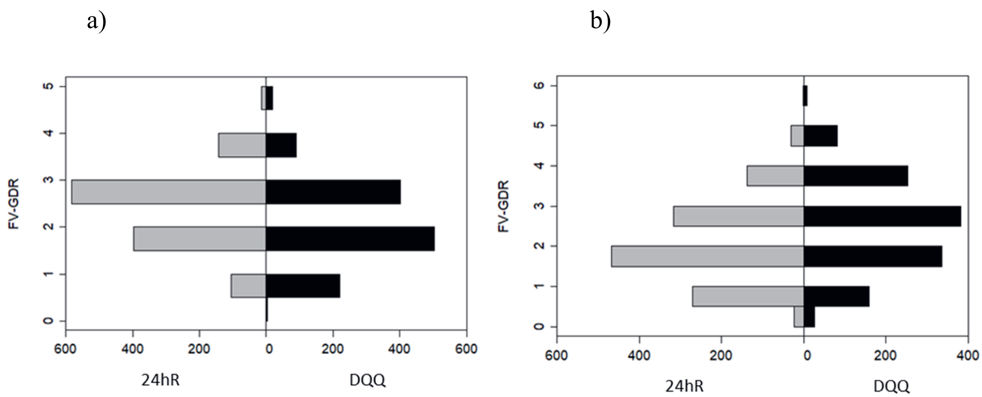

Figure S3.1 Back-to-back plots showing the distribution of FV-GDR in the a) Vietnamese and b) Nigerian study population calculated from 24hR (grey) and DQQ (black), respectively.

Table S3.6 Proportion of food groups consumed calculated from 24hR including only sentinel foods of the DQQ.

	Vietnam		Nigeria	
	n	%	n	%
Vitamin A rich vegetables	150	12.1	265	29.7
Dark green leafy vegetables	989	79.8	818	66
Other vegetables	869	70.1	1227	99
Vitamin A riche fruits	128	10.3	121	9.8
Citrus	397	32	386	31.2
Other fruits	425	34.3	345	27.8

Table S3.7 Proportion of food groups consumed when all quantities are included in the analysis for Vietnam and Nigeria

	Vietnam				**Nigeria**			
	DQQ (n=1240)		**24hR (n=1240)**		**DQQ (n=1248)**		**24hR (n=1248)**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Vitamin A rich vegetables	167	13.5	152	12.3	638	51.1	227	18.3
Dark green leafy vegetables	1013	81.7	997	80.4	823	65.9	818	66
Other vegetables	748	60.3	1055	85.1	1138	91.2	1227	99
Vitamin A rich fruits	123	9.9	129	10.4	116	9.3	121	9.8
Citrus	388	31.3	381	30.7	396	31.7	386	31.2
Other fruits	452	36.5	696	56.1	338	27.1	345	27.8
	Mean	**(sd)**			**Mean**	**(sd)**		
FV-GDR	2.33	(0.92)			2.8	(1.20)		
(min – max)	(0-5)				(0-6)			

DQQ = Dietary Quality Questionnaire; 24hR = 24hour recalls

Chapter 4

Fruit and vegetable intake of females before, during and after the introduction of three integrated food system interventions in urban Vietnam and Nigeria

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ABSTRACT

Background Low fruit and vegetable (FV) intake in low- and middle- income countries, associated with non-communicable diseases and micronutrient deficiencies, requires food system interventions addressing affordability, acceptability and accessibility of FV. Periodic monitoring of FV intake throughout the period of interventions could inform progress towards achieving increased intakes and contribute to understanding the effectiveness of nutrition interventions.

Objective This study evaluates the trend in FV intake before, during and after implementation of a set of nutrition-sensitive food system interventions over a 1-year period in Vietnamese and Nigerian urban and peri-urban females.

Methods We used the Diet Quality Questionnaire to assess FV food groups consumption among 600 Vietnamese (Hanoi) and 610 Nigerian (Ibadan) females, before, during and after the interventions. A FV score (FV-GDR) was calculated and compared between exposure groups with (mixed) count modelling. The trend in consumption of individual FV groups was analysed with mixed logistic regression.

Results The FV- GDR was stable over time and a small increase was observed after the intervention period especially in Nigeria and in urban Vietnam. A decrease in the total score was observed in peri-urban Vietnam. Fluctuations were detected in the probability of consumption of individual FV groups over time especially within the fruit groups, probably due to seasonal availability of the products. The degree of exposure could not explain differences in FV intake.

Conclusions We found a marginal increase in the proportion of females consuming FV during the interventions in both countries. The FV-GDR appeared to be a simple, quick and easy to use indicator for monitoring diversity, variety and consumption.

INTRODUCTION

The intake of fruits and vegetables (FV) is particularly low in low- and middle-income countries (LMICs) where over 80% of the population (1,2) fail to meet the daily intake requirement of 400 grams as recommended by the WHO (3). FV play an important role in preventing micronutrient deficiencies and diet-related non-communicable diseases (3). The health benefits are attributed to their high content of essential minerals, vitamins, phytochemicals and dietary fibre. These nutrients are often deficient in many diets across the globe (4,5). Low intake of FV is recognized as a risk factor for the global burden of disease and is associated with a risk of cancer, stroke, cardiovascular disease and all-cause mortality (6).

Dietary intakes and choices for FV are driven by complex combinations and interactions of psychosocial, socio-economic and environmental factors, related to food system activities (7–10). Accordingly, there is evidence that interventions focusing on the food environment, behaviour change communication, subsidies and taxes are effective strategies to promote FV consumption (11). Therefore, a food system approach is needed to make healthy foods, such as FV, accessible, acceptable and affordable to people with the ultimate goal to improve their quality of diets (12).

With this rationale, the "Fruit and Vegetable intake in Vietnam and Nigeria" (FVN) project was implemented in the context of urban and peri-urban Vietnam and Nigeria to increase FV intake among low-income urbanites through a bundle of three food system interventions addressing accessibility, affordability and acceptability of FV. These interventions included diverse retail-level innovations designed and implemented by small-scale FV (in)formal vendors, a client-specific coupon system, and promotional campaigns about the importance of eating FV daily, implemented over a 8-month period in 2020/2021 in purposely selected low-income urban and peri-urban areas in Hanoi and Ibadan. The interventions targeted (in)formal open-air vendors, because low-income urbanites mainly depend on these more traditional vending structures. In urban Hanoi, these structures contribute to 70% of the food intake among low-income populations (13), and also across sub-Saharan Africa traditional markets and informal traders remain the main source of fresh foods for low- to middle- income urbanites (14,15).

Periodic monitoring of FV intake throughout the period of intervention (16) could provide information on progress in achieving increased intakes, and contribute to the final evaluation of the interventions, to assess whether the planned objectives are being met, and contribute to the limited knowledge and understanding of the effectiveness of nutrition interventions (11,17). The repetitive nature of the data needed in such periodic monitoring asks for a simple, intuitive, replicable and non-invasive tool and indicator. Thus, the FVN project used the Diet Quality Questionnaire (DQQ) (18) for the repeated measurements of the number of FV food groups consumed the previous day, summarized in the FV score (FV-GDR). This indicator captures total FV intake and variety among FV food groups which suits the purpose of providing a preliminary evaluation of the effect of the interventions and comparison across countries.

This study aimed to assess the changes of FV intake and of single FV food groups consumed over the period of the interventions using the FV-GDR derived from the DQQ. It also evaluated the association between FV food group consumption and degree of exposure to the interventions, in urban Vietnamese and Nigerian females targeted by the FVN project.

METHODS

Study population

The participants were females aged 18-49 years from low-income households living in Hanoi, Vietnam, and Ibadan, Nigeria. Pregnant and lactating females were excluded from the study. In both cities, one urban and one peri-urban area were selected for the high prevalence of low-income households: Đống Đa and Hà Đông in Hanoi, and Abàeja and Bagadajé in Ibadan. Participants were selected from the lists of households residing in the selected areas that included at least one female aged 18-49 years, provided by community health workers in Vietnam and the local project team in Nigeria. Part of the respondents were recruited in 2019, at the beginning at the FVN project, and part in 2020. The reason of the two different rounds of recruitment is the large dropout of females after a break of the project imposed by COVID-19 pandemic. When it became possible to start with the implementation of the interventions, new respondents were selected to replace the dropout using the same selection method. Data analysis for this study comprised only those that stayed in the study and the replacements of the dropouts, excluding those lost to follow-up during the period of the interventions.

FVN project

The three FVN interventions initially aimed at improving i) the accessibility by enlarging the diversification of the FV assortment of FV vendors, ii) the affordability by means of a client-specific coupon system and iii) the acceptability through a promotional campaign about the importance of eating daily FV. All country-specific interventions were then further developed based on data on the dietary intake (19) and knowledge, attitude and practices around FV consumption (20,21) of the study population, barrier analysis (22), product seasonality (23,24) and market assessment (25,26) of the studied areas. Although the first intervention (i) initially envisaged to focus solely on accessibility, in the end, it focused on affordability and acceptability, as a result of the participatory co-creation method employed. Various innovations were tested, including improved point of sales and product display (Nigeria), improved marketing (Vietnam and Nigeria), delivery of nutritional information to consumers (Vietnam and Nigeria), improved food safety and customer service practices (Nigeria) and set-up of a loyalty card system (Vietnam). This intervention was implemented for eight months, in both countries.

The second intervention (ii) consisted of the distribution of coupons of two different monetary values (Vietnam: 30,000/60,000 Vietnamese dong; Nigeria: 400/800 Nigerian naira) to purchase a selection of fruit items (8 in Vietnam and 9 in Nigeria) from selected FV vendors. In Vietnam, coupons were delivered to randomly selected sample households on a biweekly basis, first by a delivery service and then by community health workers two months after the project began. In Nigeria, sets of coupons were delivered to randomly selected sample households by project staff on a weekly basis. In both countries, coupons expired two weeks after they were received by households and could be redeemed at the retail outlets of participating vendors. The coupon intervention lasted five months in both countries.

The third intervention (iii) involved a series of neighbourhood-specific campaigns aimed to promote the importance of adequate daily FV consumption, which were developed and reviewed through a series of four co-creation workshops engaging low-income residents from the study areas. In Vietnam, communication materials (pamphlets, posters) focused messaging around the health benefits of FV, variety, seasonality, WHO recommended intake of 400 g/day, food safety and home production, and they were disseminated by local health centres through social media platforms, market events, training courses, and loudspeaker announcements (Hà Đông only). In Nigeria, messaging in the communication materials (pamphlets, posters, branded merchandise, jingles, dramas and expert talks) highlighted disease prevention, WHO recommended intake of 400 g/day, affordability, food safety, home production, variety and seasonality, and campaigns were carried out through radio stations, primary health care centres, religious centres and schools.

All three interventions targeted consumers and FV vendors within the selected study areas. Therefore, the first intervention at the vendor level and the promotional campaign targeted all selected respondents. In contrast, the coupon system followed a randomized control trial design with part of respondents receiving the intervention (coupons) and others not (control group). A total of 600 Vietnamese and 610 Nigerian females were included at FVN baseline, which declined to 494 Vietnamese and 473 Nigerian at end-line. The main reasons for loss to follow-up were the unwillingness to continue, the unavailability at the time of interviews or migration outside the study area.

Ethical approval

Ethical approvals for the aforementioned research project were obtained prior to the start of the study from Hanoi Medical University Institutional review Board in Hanoi (45-18/HMU-IRB) and University of Ibadan/University College Hospital Ethical review Committee (UI/UCH-ERC) in Nigeria (HNHREC/05/01/2008a). All participants signed an informed consent before the start of the study and confirmed the consent by phone before the subsequent data collection rounds.

Study design and dietary assessment

The study was designed as a panel and participants were followed for one year. Dietary intake data was collected every two months for a total of six timepoints (T1 – T6). The first assessment (T1) was performed before the start of the interventions; T2, T3, T4, and T5 during the interventions; and T6 post-interventions. Dietary assessment at T6 was performed 3 months after the end of the interventions in Vietnam, and immediately after the end of the interventions in Nigeria. The 3-months delay of data collection faced in Vietnam was because the planned home visits were restricted by governmental directives imposed from July to September 2021 to limit the spread of COVID-19 pandemic. Data on FV intake were measured in Vietnam between 28 July 2020 and 27 September 2021; and in Nigeria between 24 November 2020 and 15 December 2021. Data were collected with a DQQ, a simple, relatively quick method and of low burden for interviewers and participants (18). The questionnaire consists of 29 dichotomous questions (yes/no) on the food groups consumed the previous day, including a list of country specific sentinel food items within the same food group. The DQQ was administered as part of a larger survey in T6, but it was administered in the first module to minimize any potential effects of survey fatigue, which could cause differences between answers in T6 and T1 through T5. Additionally, a questionnaire was administered at T1 to obtain socio-demographic information and at T6 to assess the self-reported exposure to the interventions. Due to the governmental restrictions to limit the spread of COVID-19, data were collected via phone and, when possible, in person interviews performed by local researchers using digital forms in KoboToolbox software (27) in both countries.

Variables

The six FV groups (*dark green leafy vegetables, vitamin A-rich orange vegetables, other vegetables, vitamin A-rich fruits, citrus, other fruits)* from the DQQ were used to create the FV score (FV-GDR) as the main outcome. The FV-GDR ranges from 0, meaning no FV groups consumed during the previous day, to 6, when all FV food groups were consumed. It was assumed that a higher score indicated a higher and more diverse intake of FV at population level. For individual FV groups, a dichotomous score (0-1) was created to indicate whether the food group was consumed or not at each timepoint. Based on the self-reported information, respondents were categorized into four groups according to exposure to the interventions in the previous year: *not exposed* (0), *exposed to one intervention* (1), *exposed to two interventions* (2) and *exposed to all interventions* (3). As the degree of exposure was assessed only at T6, the association between FV-GDR and exposure to the interventions was investigated only with data from respondents who were interviewed at T6.

Data analysis

Data was first explored with descriptive statistics for socio-demographic information at baseline and FV food groups consumed at each timepoint. Potential confounders and effect modifiers were identified for all studied associations. The confounders assessed were (1) area, age and household size because FV intake might vary based on individual and household characteristics (22); (2) baseline FV-GDR because influences the possible changes in consumption; and (3) education, occupation and food insecurity because underprivileged females possibly have a lower FV intake (28,29). These indicators were also studied at each timepoint to check for confounders that could have been introduced by loss to follow-up (30). The only effect measure modifier that was assessed was area since availability and accessibility of FV groups and exposure to the interventions could vary between locations (31). As area was found to be an effect measure modifier in all models for Vietnam, we decided to analyse data separately for urban and peri-urban areas for both countries.

The change in the total FV-GDR (ranging from 0 to 6) at population level over the six timepoints was analysed with a generalized Poisson regression, selected because the count data were found to be under-dispersed (32). Timepoints were included in the model as independent variables and the FV-GDR as a dependent variable. A random intercept and random slope were added to fulfil the assumption of independency of measurements within persons. The changes in the probability of consumption of individual FV groups were analysed over time with mixed effects logistic regression models. Having consumed or not a specific FV group on the previous day was the dependent variable of each model, timepoints were the independent variables and estimated coefficients reflected probabilities of consumption. For both analysis, measurement dependency was assessed by the likelihood ratio tests and Intraclass Correlation Coefficients (ICC). Random intercept and a random slope were added to correct for the measurement dependency only in the models with ICC >0.05 (33,34). For these models, the differences between the model with or without random intercept and random slope were checked. If no difference was found, the simplest model was kept.

To study the association of exposure to the interventions and the FV-GDR, we developed a count model with exposure to intervention as independent variable and FV-GDR as dependent variable. FV-GDR at T5 and at T6 were compared to the degree of exposure to the interventions. T5 was chosen because participants were most likely to have been exposed to the interventions during the previous year; and T6 provided information on the lasting effect on FV-GDR post-interventions. Area was included as covariate only in the models of Vietnam as this was found to be associated to exposure to the interventions and FV-GDR. For each model all covariates were tested, and the final model was selected based on the lowest Akaike Information Criterion and Bayesian Information Criterion. Data analysis was performed with Stata (35) software and performed separately for Vietnam and Nigeria.

RESULTS

General characteristics

In Vietnam, half of the participants were from Đống Đa (50%) and the mean age of the study population was 35 (8.2) years (Table 4.1). On average, females lived in a household of 5 people, had two children and were married (92%). Females were mainly employed with a regular salary (44%) and in Hà Đông, more people were employed in *crop production and livestock raising* compared to Đống Đa (14% and 0.3%, respectively). In general, most participants *finished high school* (33%) but participants in urban area were more likely to be higher-educated.

In Nigeria, 48% of the participants were from Abàeja and the mean age of the study population was 35 (8.3) years. On average, females lived in a household of 5 people, had 3 children and were married, either monogamously (77%) or polygamously (9%). Most females had finished *secondary school* (57%) and *trading* was the most dominant employment sector (52%) followed by working in the *artisan/handicraft* (26%) sector.

Trend of total FV-GDR

In Vietnam, Đống Đa had a lower FV-GDR at T1 compared to Hà Đông (3.46, 95%CI 3.34 - 3.59 versus 2.60, 95%CI 2.50 - 2.70) (Figure 4.1A). In Đống Đa, the FV-GDR was relatively stable over time from T1 to T5 and increased by almost one point from T5 to T6 (from 2.85, 95%CI 2.73 - 2.97 to 3.73, 95%CI 3.58 - 3.88). In contrast, a downward trend in FV-GDR was shown in Hà Đông from T1 to T5. However, it slightly increased from T5 to T6. At T6 Đống Đa had a higher FV score compared to Hà Đông. In Nigeria, the two areas followed a similar trend in mean FV-GDR over time (Figure 4.1B). The FV-GDR was relatively stable over all timepoints and ranged from 3.00, 95%CI 2.87 – 3.13 to 3.48, 95%CI 3.34 – 3.62. In both areas, a small increase in the mean FV-GDR was observed between T1 and T3. Moreover, the FV-GDR at T6 were slightly higher compared to T1 in both areas.

Table 4.1 Sociodemographic characteristics of the study population of Hanoi, Vietnam and Ibadan, Nigeria at baseline measurement per area

	Vietnam			Nigeria		
Distribution over areas	**Hanoi (total)**	**Đống Đa (urban)**	**Hà Đông (peri-urban)**	**Ibadan (total)**	**Abàeja (urban)**	**Bagadajé (peri-urban)**
n	600	297	303	610	296	314
Urban area , % (n)	49.5 (297)	100 (297)	0	48.5 (296)	100 (296)	0
Age, mean ± SD[1]	35.1 ± 8.2	35.2 ± 8.5	35.1 ± 7.9	34.7 ± 8.3	34.7 ± 8.4	34.7 ± 8.2
Household size, mean ± SD[2]	4.8 ± 1.9	4.9 ± 1.5	4.7 ± 2.3	5.2 ± 2.0	4.9 ± 1.9	5.4 ± 2.1
Number of children, mean ± SD[1,2]	2.0 ± 0.9	2.2 ± 0.9	1.7 ± 0.8	2.8 ± 1.8	2.6 ± 1.8	3.1 ± 1.7
Main occupation, % (n)[3]						
Crop production/livestock	7.2 (43)	0.3 (1)	14.0 (42)	0.3 (2)	0.7 (2)	0.0 (0)
Trading	11.9 (71)	13.8 (41)	10.0 (30)	52.1 (318)	48.0 (142)	56.1 (176)
Salary employment	44.4 (265)	52.2 (155)	36.7 (111)	10.5 (64)	11.8 (35)	9.2 (29)
Non-agriculture daily labourer	16.3 (97.3)	8.4 (25)	24.0 (73)	0.0 (0)	0.0 (0)	0.0 (0)
Unpaid housework	5.9 (35)	6.4 (19)	5.3 (16)	1.3 (8)	0.7 (2)	1.9 (6)
Artisan/Handicraft	0.0 (0)	0.0 (0)	0.0 (0)	26.2 (160)	25.3 (75)	27.1 (85)
Other	14.4 (86)	18.9 (56)	10.0 (30)	9.5 (56)	13.5 (40)	5.7 (18)
Highest education level, % (n)[1,2]						
Primary school	4.9 (29)	1.4 (4)	8.4 (25)	19.3 (118)	16.6 (49)	22.0 (69)
Secondary school	24.1 (144)	10.4 (31)	37.7 (114)	57.4 (350)	55.7 (165)	58.9 (185)
High school	32.7 (196)	31.3 (93)	34.0 (103)	NA	NA	NA
Tertiary institution	37.4 (224)	55.6 (165)	19.2 (58)	20.8 (127)	24.7 (73)	17.2 (54)
Other	1.0 (6)	1.4 (4)	0.7 (2)	2.5 (15)	3.0 (9)	1.9 (6)
Marital status, % (n)[1,2]						
Single	5.7 (34)	7.1 (21)	4.4 (13)	10.0 (61)	12.5 (37)	7.6 (24)
Married, monogamous	91.8 (550)	90.2 (268)	93.3 (277)	77.0 (470)	73.6 (218)	80.3 (252)
Married, polygamous	NA	NA	NA	9.0 (55)	7.5 (22.2)	10.5 (33)
Other	2.5 (15)	2.7 (8)	2.4 (7)	3.9 (24)	6.4 (19)	1.6 (5)

NA = not applicable; [1] 1 missing value in Nigeria; [2] 6 missing value in Vietnam, [3] 3 missing values in Vietnam

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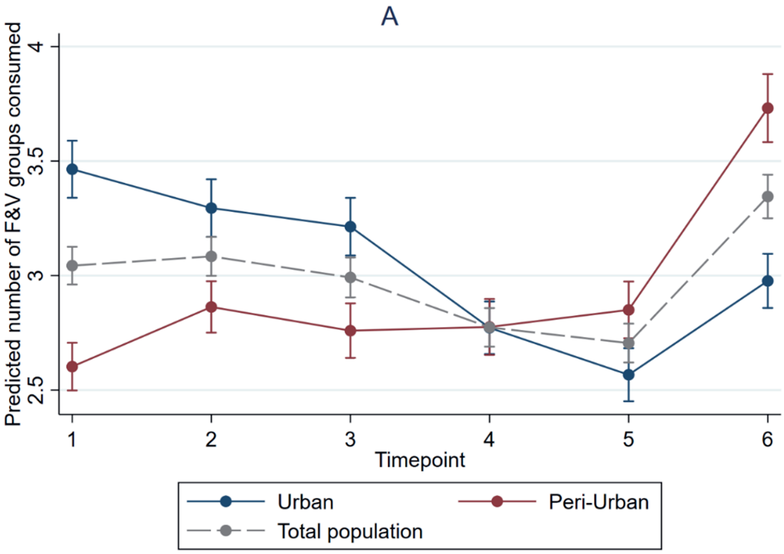

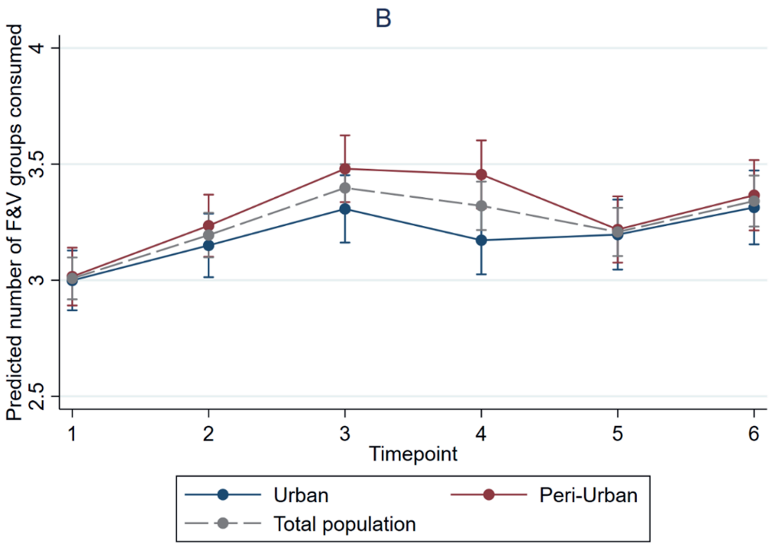

Figure 4.1. Predicted mean FV-GDR with 95% CI at six timepoints of females from A) Đống Đa (urban) and Hà Đông (peri-urban), Hanoi and B) Abàeja (urban) and Bagadajé (peri-urban), Ibadan. Timepoint 1=pre-interventions, 2-3=two interventions implemented, 4-5=three interventions implemented, and 6=post-interventions. No evidence was found for confounding by area, age, household size, baseline FV-GDR, education, occupation and food insecurity.

Trend of single fruit and vegetable groups

The trend of consumption over time differed for the individual FV groups and differences were observed between areas in the Vietnamese population (Figure 4.2). In general, low consumption of vit A-rich orange vegetables was observed and the probability of consumption increased over time for Đống Đa, whereas it decreased for Hà Đông. The probability of consumption of dark green leafy vegetables was high and stable throughout the year for both areas. The trend of consumption observed for the other vegetables was stable from T1 to T5. However, it increased at T6 in Đống Đa, whereas in Hà Đông it increased at T2 and T3, but decreased afterwards with the lowest probability at T6. The probability of consumption of vit A-rich fruits was low all year round but increased over time for Đống Đa, with probabilities twice as high at the last three timepoints; whereas, in Hà Đông, the highest probabilities were observed at T1 and T4. A large variation in consumption levels over time was shown within the citrus group. The highest probabilities were observed at T2 and T3, which were 3-4 times higher compared to T1 and T5 in both areas. Large variation over time was also shown for the other fruit group with the highest probabilities of consumption at T1, T5 and T6 in both areas.

In Nigeria, the trend of consumption over time differed for the individual FV groups, but they were similar in the two areas (Figure 4.3). The probability of consumption for the three vegetable groups was high and stable. A small increase was observed in the probability of consumption of vit A-rich orange vegetables from T1 to T2 and of dark green leafy vegetables from T1 to T3, with a small decrease from T3 to T6. The probability of consumption of the other vegetables group was the highest and the most stable over time. The probability of consumption of vit A-rich fruits was low all year round except from T2 to T3 when consumption doubled. Most variation over time was observed for citrus and other fruits groups. The probability of consumption of citrus dropped at T3 to a level more than twice as low as T1; it increased between T3 and T6 reaching the same level as T1. In contrast, other fruits group showed an upward trend between T1 and T3. First, the probability almost doubled, and then it decreased between T3 and T6.

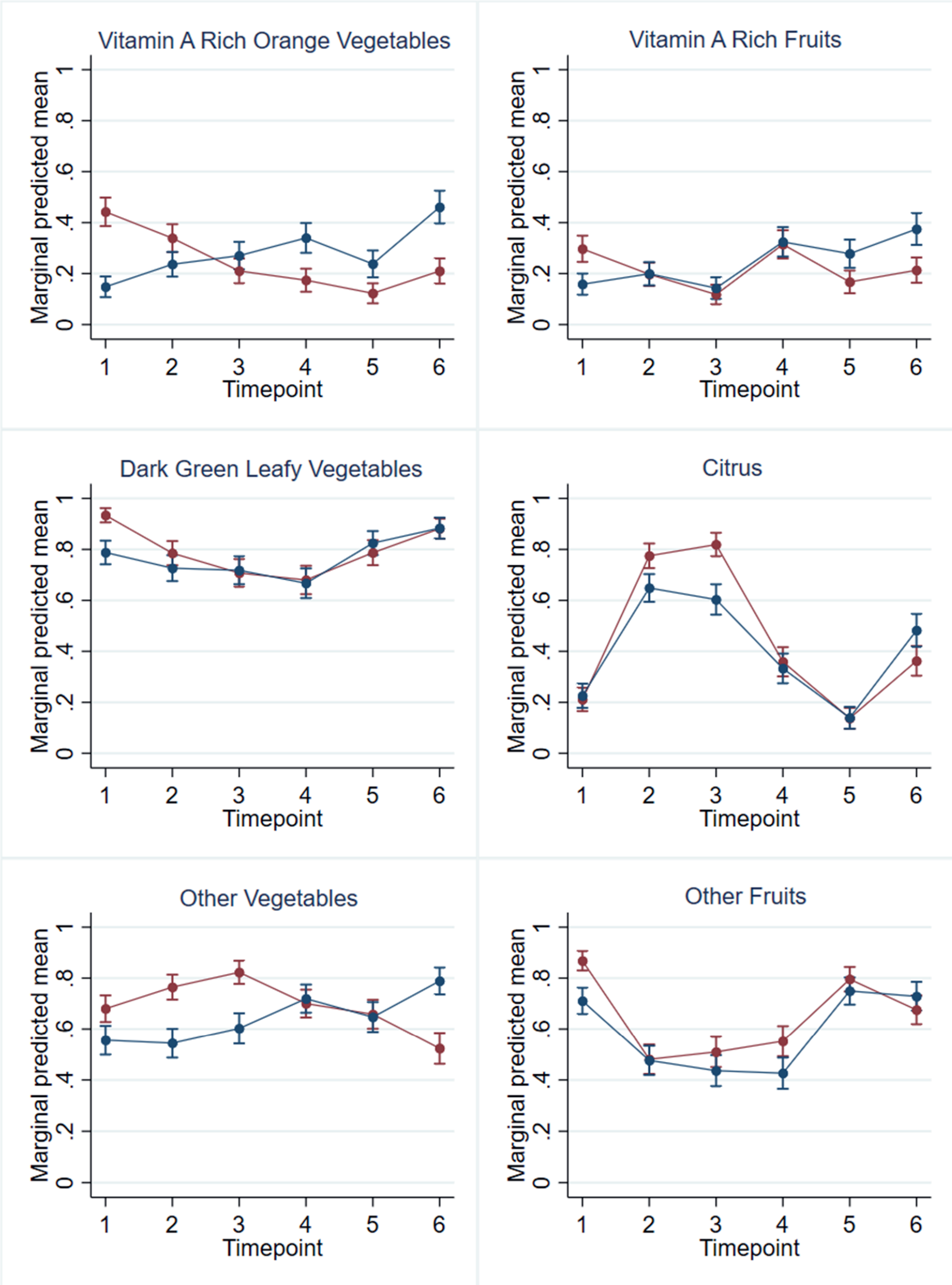

Figure 4.2 Mean probabilities of having consumed individual FV groups at each timepoint with 95% CI in Hanoi, Vietnam for Đống Đa (urban) and Hà Đông (peri-urban). Timepoint 1=pre-interventions, 2-3=two interventions implemented, 4-5=three interventions implemented, and timepoint 6=post-interventions.

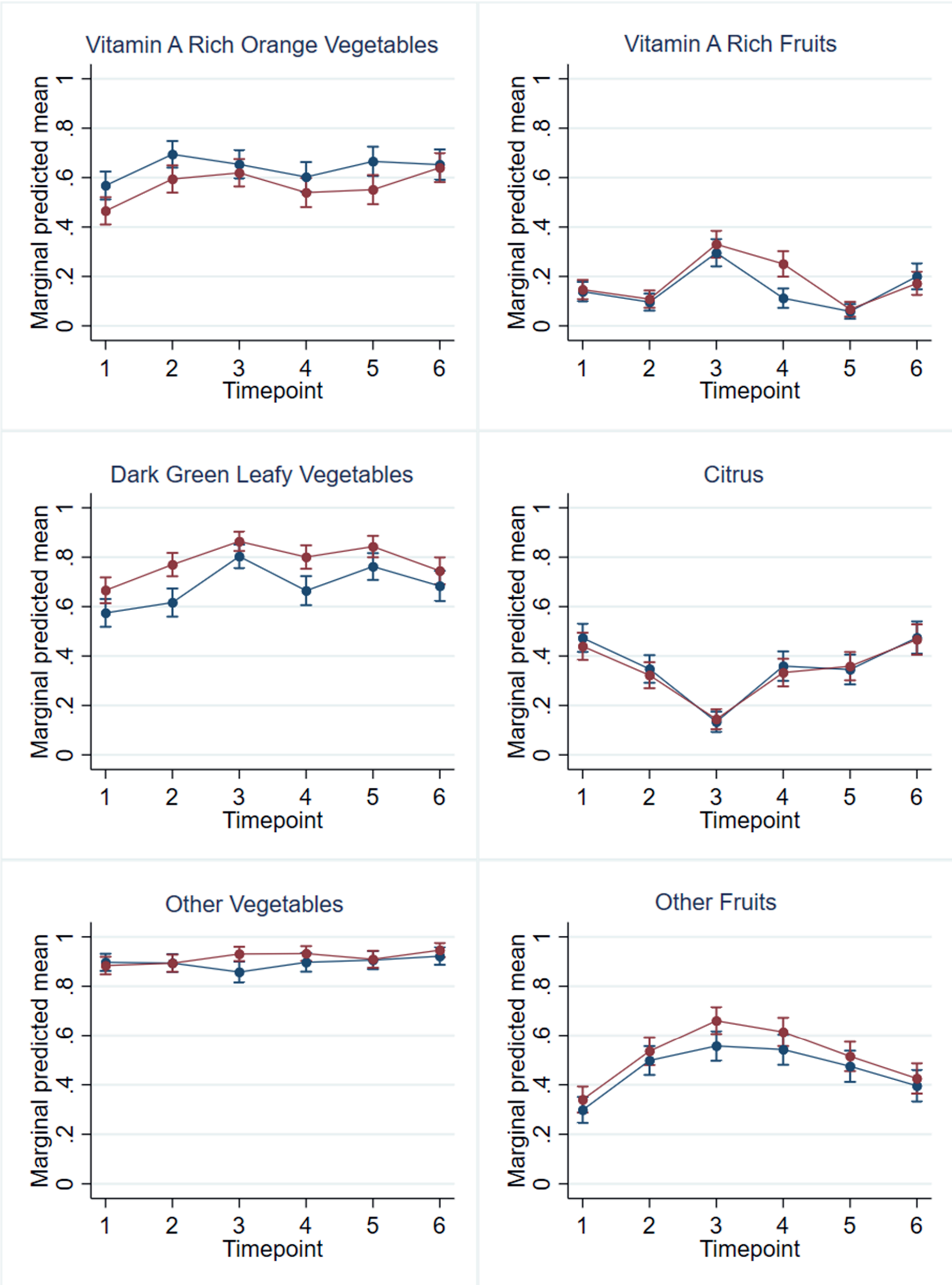

Figure 4.3 Mean probabilities of having consumed individual FV groups at each timepoint with 95% CI in Ibadan, Nigeria for Abàeja (urban) and Bagadajé (peri-urban). Timepoint 1=pre-interventions, 2-3=two interventions implemented, 4-5=three interventions implemented, and 6=post-interventions.

Association between exposure to the interventions and FV-GDR

In the total of 494 Vietnamese participants interviewed at T6, 18.4% of the population reported not being exposed while 26.7%, 34.0% and 20.9% reported being exposed to one, two or three interventions, respectively. The mean FV-GDR of the exposure groups were relatively similar but slightly higher at T6 compared to T5, ranging from 2.65, 95%CI 2.50 - 2.79 to 2.85, 95%CI 2.68 - 3.0 at T5, and from 3.11, 95%CI, 2.87 - 3.34 to 3.46, 95%CI 3.22 - 3.70 at T6 (Figure 4.4A-D). In the total of 473 Nigerian participants interviewed at T6, all reported to be exposed, of which 4.2%, 37.2% and 58.6% of the population was exposed to one, two or three interventions, respectively. The mean FV-GDR of the exposure groups ranged from 2.97, 95%CI 2.55 – 3.40 to 3.42, 95%CI 3.29 – 3.56 at T5; and from 3.20, 95%CI 2.72 – 3.68 to 3.42, 95%CI 3.29 – 3.56 at T6. No large differences were observed in mean FV-GDR between the exposure groups both at T5 and T6.

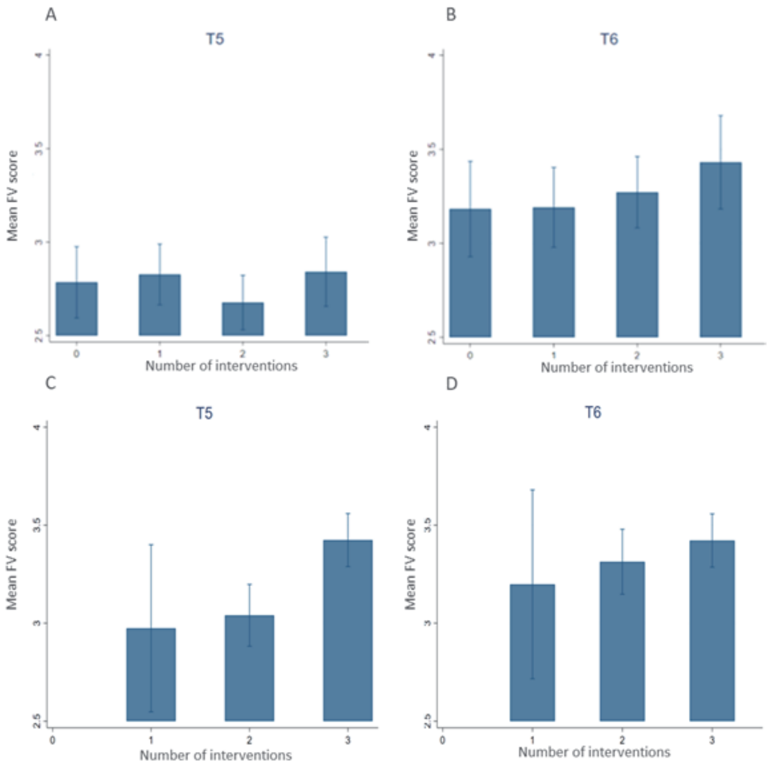

Figure 4.4 Mean FV-GDR with 95%CI compared between exposure groups at T5 (n=521 Vietnam; n=505 Nigeria) and T6 (n=494 Vietnam; n=473 Nigeria) for Vietnam (A-B) and Nigeria (C-D). 0=not exposed, 1=exposed to one intervention, 2=exposed to two interventions, 3=exposed to all interventions. The model was adjusted for area in Vietnam. FV-GDR of the

non-exposed could not be calculated as all participants were exposed to at least one intervention.

DISCUSSION

In this study we investigated the consumption trend of the total and single FV food groups during the FVN project in urban and peri-urban Vietnamese and Nigerian females. While the total FV consumption did not vary strongly over the intervention period in either country, the intakes of single FV group, especially fruits, fluctuated over time. In Vietnam, we also found differences in FV consumption and changes herein between urban and peri-urban areas.

In both countries, we found that the total FV-GDR remained stable over the study period, with only a slight increase in both countries. This finding suggests that the number of females consuming FV and the diversity and variety of FV consumed did not drastically change over the intervention period. However, it is uncertain whether this also indicates that the quantities consumed were stable over time, because the DQQ does not directly capture information on the quantities consumed since only consumption (yes/no) of food groups is reported. In settings where a low proportion of females consume FV, an increase in this proportion would indicate an increase in FV intake (36). However, in settings where FV are commonly consumed by most of the females but in inadequate amounts, the FV intake can only be improved by increasing portion sizes. In the first setting the FV-GDR will capture the change, but in the latter will not be able to reflect changes in intake. This could also explain the stable score of vegetable intake as on average 98% and 96% of the population consumed vegetables in Vietnam and Nigeria, respectively. For fruits, in both countries, these percentages were lower (62% in Vietnam and 71% in Nigeria), and hence, the fluctuation may better reflect the changes in amounts of fruit consumed.

Contrary to the relative stability of total FV-GDR, we did see large variation in consumption of individual FV food groups over the year and more for fruits than for vegetables in both countries. These trends largely followed the seasonal availability of FV, a major determinant of consumption in a population that relies on short food chains, where availability, diversity and affordability are shaped by the seasons (37). The consumption of *citrus fruits* during the dry season and *vitamin A rich fruit and vegetables*, and *other fruits* during wet season follow the peaks in availability of these fruits (23,24). The FV-GDR is indeed a suitable indicator to detect seasonal fluctuation of consumption because of its dichotomous nature. A higher score reflects the consumption of the food group, implying that specific FV are available and accessible at a certain times of the year. As, according to a preliminary cross-sectional study by Herforth et al. (36), the FV component of the DQQ positively correlates with FV consumption, the fluctuation of the FV-GDR in our study shows periods of low and high intake of fruits through the year.

In Vietnam, we found an increased intake trend of total FV in the peri-urban area, but not in the urban area. This was mainly due to an increase in the proportion of females reporting consumption of *vitamin A rich fruits*, *vitamin A rich orange vegetables* and *other vegetables*. The difference between peri-urban and urban areas could be partially explained by the production of FV by households in the peri-urban area. As Hà Đông was recently added to the city boundaries, several peri-urban households still have vegetables and fruit tree gardens used for household consumption (38). This production could have also contributed to maintaining consumption during the intervention period, which was characterized by disruptions of transportation and markets, fluctuation of prices, and limited mobility due to COVID-19 pandemic (39). Moreover, limited access to wet markets in urban areas and widespread absence of storage facilities for fresh foods may have affected food choices and consumption (40). Availability of own produce might have mitigated these effects in peri-urban areas while households in urban areas might have been compelled to reduce their FV consumption (40).

Due to the non-randomized placement of two of the three interventions and the absence of a control group, we cannot attribute changes in our outcome variables to the interventions. These prevented controlling for the effect of temporal factors influencing the study outcome other than the interventions, such as COVID-19 measures put in place to limit the spread of the pandemic. We may speculate that being exposed to the interventions protected females from COVID-19 related disruptions to the food system possibly leading to decrease in FV consumption. Some studies are indicating this negative effect on diet quality (41,42) while others suggest an increased intake because of the believed boosted immunity (43–45). However, the design of and data available from our study does not allow us to test this hypothesis directly.

To note an effect, we associated the FV-GDR to the degree of exposure to the interventions, i.e. having been involved in 1, 2 or 3 of the interventions. This was based on self-reported experienced exposure, which might have been underreported as the promotional campaign in the market environment and local vendors could have been unconsciously experienced by the respondents but not reported. In addition, the loss to follow-up of 20% could have introduced a selection bias at T5 and T6. People exposed to the interventions could have more likely stayed involved in the study because they were more aware of the benefits of FV. However, sociodemographic characteristics and the baseline FV-GDR of people lost to follow-up were comparable to the participants that were involved until the end.

Overall, monitoring the project outcomes over the period of the interventions allowed to identify the direction and trend of FV intake. In this study, the FV-GDR was selected as indicator because it is simple to administer, quick and relatively cheap. Although it did not provide information about FV quantities, other aspects of FV intakes, such as diversity, variety and fluctuation over the seasons were captured. Additionally, the use of FV-GDR and count modelling allowed comparison across different contexts and a broader outcome range compared to a binary score. Furthermore, the longitudinal study design is appropriate for monitoring nutrition interventions and capturing seasonal effects. Lastly, implementation of the interventions in an urban and a peri-urban area of two different countries provided accurate insights of FV intakes in different settings and contexts.

CONCLUSION

In conclusion, we found a marginal increase in the proportion of urban females consuming FV during the interventions in Vietnam and Nigeria. The FV-GDR appeared to be a simple, quick and easy to use indicator for monitoring diversity, variety and consumption.

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Chapter 5

Evaluation of integrated interventions targeted at fruit and vegetable consumption in low-income urban and peri-urban adults: using a food system approach in Vietnam and Nigeria

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ABSTRACT

Background Fruit and vegetable consumption is globally below the WHO recommendations, and Southeast Asia and West Africa are among the regions with the lowest consumption. Affordability, accessibility, and acceptability are the main drivers of consumption. Nutrition-sensitive food system interventions that address these drivers may be effective in increasing fruit and vegetable consumption.

Objective This study evaluates the effect of an integrated nutrition-sensitive project that aimed to increase fruit and vegetable consumption in low-income urban adults in Hanoi, Vietnam, and Ibadan, Nigeria, through the simultaneous implementation of three interventions at the market and consumer levels.

Methods Fruit and vegetable intake data were collected after eight months of exposure to the project with repeated quantitative 24-hour recalls and compared between an exposed (Vietnam n=283; Nigeria n=291) and a control group (Vietnam n=299; Nigeria n=335), considering potential confounders: age, sex, neighbourhood, BMI, household size, education and occupation.

Results The adjusted intake of total fruits and vegetables (169 g/d, 95%CI 132, 205), fruits (156 g/d, 95%CI 122, 193) and vegetables (12 g/d, 95%CI -2, 26) was higher in the exposed Nigerian population compared to the control group. In Vietnam only intake of fruit (24 g/d, 95%CI 12, 34) was higher in the exposed group. Participants exposed to all three interventions reported slightly higher intakes compared to those who were exposed to fewer interventions, but these differences were not statistically significant.

Conclusions Our results suggest that integrated approaches of nutrition-sensitive food system interventions may offer a potential to increase fruit and probably also vegetable consumption. Co-creation of interventions provides the possibility to address the differences across contexts.

INTRODUCTION

Dietary guidelines vary across countries but healthy diets are globally defined as rich in fruits and vegetables (FV), nuts and seeds and unrefined grains, and low in highly processed foods, sugar, salt and fats (1). Specifically, a considerable daily intake of diverse FV (400g/d) (2) is recommended as protective for all-cause mortality and prevent micronutrient deficiencies as well as diet-related non-communicable diseases, such as cancer, diabetes and cardiovascular diseases, due to their antioxidant compounds, vitamins, minerals and fibre content (3,4). However, globally, FV intake is below the recommendations with, on average, less than 100 grams of daily fruits and less than 200 grams of daily vegetables consumed (5). Especially in many low- and middle-income countries (LMICs) the average intake of FV is lower than recommended (6,7), with Southeast Asia (100 g/d fruits; 150 g/d vegetables) and West Africa (80 g/d fruits; 110 g/d vegetables) being among the regions with the lowest consumption (5). Therefore, promoting increased FV intake is one of the key strategies towards healthier diets (8).

FV consumption is driven by multiple interlinked social, environmental and economic barriers and enhancers (9,10), both at the individual and external levels. At the individual level, affordability, accessibility and acceptability are the main drivers of consumption (11). Affordability is the combination of individual purchasing power and market prices and determines to a large extent what food items are bought and consumed. Diet quality is positively correlated to the cost of the diet, resulting in healthy diets being unaffordable for many people, especially low-income groups (12–15). Accessibility refers to factors such as time, distance, space and means of transportation that enable an individual to reach the available foods. Proximity to markets and retailers, reduced travel time and having more time for cooking positively influence diet quality and food security (16–18). Acceptability refers to the cultural preferences, knowledge and attitudes towards food products and consumption habits. Socio-demographic characteristics, such as education level, have been positively linked to acceptability and diet quality (19,20) and food preferences and choices largely vary across countries (21).

Numerous entry points exist to increase FV consumption through a food system approach, such as intervening in food production, handling, storage and processing, food trade and marketing, consumer demand, food preparation and preferences (22,23). In recent years, it has been recognized that the effectiveness of food system programmes is higher when incorporating multiple strategies, implemented for a longer period and co-created with the target groups (24,25). Specifically, community-based multicomponent interventions were found to have positive effects on FV consumption, although studies in LMICs are limited (26).

The “Fruit and vegetable intake in Vietnam and Nigeria” (FVN) is a multi-country and multi-sectorial project that aimed to improve the quality of the diet in urban and peri-urban contexts of Hanoi, Vietnam, and Ibadan, Nigeria, focusing on increasing FV consumption. This nutrition-sensitive project included a package of three distinct interventions that were co-created with vendors and consumers attempting to address accessibility, affordability and acceptability.

Our main aim was to evaluate the overall FVN project by assessing the FV intake of the target populations at the end of the intervention period and compared these with the intakes of similar populations not exposed to the project hypothesizing that the exposed groups would consume more FV. Secondly, as an exploratory analysis, we estimated the effect of the combination of the three interventions co-created to address accessibility, affordability and acceptability and explored whether exposure to multiple interventions could positively impact the FV intake more than a single intervention.

METHODS

A cross-sectional study was conducted in Hanoi, Vietnam, and Ibadan, Nigeria, to assess the FV intakes after the implementation of a package of three FVN interventions among a random sample from the intervention area and compared this with the intakes of a random sample from a control area. The intervention package and project approach are presented in Figure 5.1. Evaluations of the single FVN interventions are reported elsewhere.

Study population and areas

The evaluations were conducted among adults aged 20-51 years (females and males) of low-income households in urban and peri-urban neighbourhoods of two cities in Vietnam (Hanoi) and Nigeria (Ibadan). In Vietnam, the urban neighbourhoods of Đống Đa (exposed) and Nam Từ Liêm (control) were selected because of their central position and higher prevalence of low-income households; the peri-urban neighbourhoods of Hà Đông (exposed) and Thanh Trì (control) were selected as they were recently included into the city’s boundaries and also have a high prevalence of low-income households. In Nigeria, the urban neighbourhoods of Abàeja (exposed) and Apete (control) and the peri-urban neighbourhoods of Bagadajé (exposed) and Ariyibi (control) were selected based on the high prevalence of low-income households. The control neighbourhoods were selected at the end of the interventions in both countries. In Vietnam, a list of eligible households was developed for each study neighbourhood by the community health workers of each neighbourhood; while in Nigeria, this list was developed for each study neighbourhood by the local research team. In both countries, the lists of eligible households were compiled prior the start (for the exposed groups in 2019), and at the end (for the control groups in 2021) of the interventions. In Vietnam, low-income households were defined as households with a monthly income <2,650,000 Vietnamese dong (VND) per capita based on the lowest 30% of the population in 2017 (27)); in Nigeria, low-income households were identified by the local research team evaluating the status of the house (Table S5.1). From the compiled lists in both countries, a total of 100 households including a non-pregnant and non-lactating female were randomly selected from each neighbourhood and checked for eligibility. For the intervention neighbourhoods females of reproductive age (18-49) were selected at the start of the intervention period, being aged 20-51 years after the two-year period of preparation and implementation of the interventions. For the control neighbourhoods, females aged 20-51 years were selected at the end of the interventions, to align with the age of the study population of the intervention neighbourhoods. In both the intervention and control groups a male from the same household was included only if available in the household at the time of the interview. The selection of the population is represented in the supplementary material (Figure S5.1).

Ethical approval

Ethical approvals were obtained before the start of the FVN project from the Hanoi Medical University Institutional Review Board in Hanoi (45-18/HMU-IRB), the University of Ibadan/University College Hospital Ethical Review Committee (UI/UCH-ERC) in Nigeria (HNHREC/05/01/2008a), and the International Food Policy Research Institute's Institutional Review Board (IFPRI IRB-007490). The randomized control trial associated with the affordability intervention was registered with the American Economic Association's registry (AEARCTR-0007701). All participants signed an informed consent before the start of the study.

FVN interventions

The FVN project consisted of a package of three interventions aiming to increase FV intake of low-income urban and peri-urban consumers intervening at both the market and demand sides (Figure 5.1). It included interventions aiming to address accessibility, affordability, and acceptability of FV. The three country-specific interventions were designed based on preliminary information on FV consumption and practices of the study population (28), on a market (29) and a seasonality assessment (30,31) of the study areas, and analysis of the main barriers for FV consumption (32). The first intervention (A) was designed using a participatory co-creation approach with local FV vendors and aimed to address accessibility of FV. This intervention included various innovations such as improved point of sales and product display (Nigeria), improved marketing (Vietnam and Nigeria), delivery of nutrition information to consumers (Vietnam and Nigeria), improved food safety and customer service practices (Nigeria) and set-up of a loyalty card system (Vietnam). This intervention was implemented for eight months in both countries. The second intervention (B) addressed affordability and consisted of the distribution of coupons of two different monetary values (low: 30,000 VND and 400 Nigerian naira (₦); high: 60,000 VND and 800 ₦) to purchase a selection of items (8 fruits in Vietnam; 7 fruits and 2 vegetables in Nigeria) from selected FV vendors. Coupons were delivered to randomly selected sample households, expired two weeks after they were received and could be redeemed at a set of participating vendors at selected markets. In Vietnam, coupons were delivered on a biweekly basis, by a delivery service for the first two months and then by community health workers. In Nigeria, coupons were delivered by project staff every week. This intervention was implemented for five months in both countries. The third intervention (C), addressing acceptability and developed and reviewed through four co-creation workshops engaging low-income consumers, involved a series of neighbourhood-specific campaigns aimed at promoting the importance of adequate daily FV consumption. In Vietnam, communication materials (pamphlets, posters) focused messaging around FV health benefits, variety, seasonality, recommended intake, food safety and home production. They were disseminated by local health centres through social media platforms, market events, training courses, and, only in Hà Đông, by loudspeaker announcements. In Nigeria, messaging in the communication materials (pamphlets, posters, branded merchandise, jingles, dramas, and expert talks) highlighted FV disease prevention, affordability, food safety, home production, variety and seasonality, and campaigns were carried out through radio stations, public health centres, religious centres and schools. This intervention was implemented for eight months in both countries. In both countries, interventions A and C started at the same time (December 2020 in Vietnam; February 2021 in Nigeria), intervention B started three months later (February 2021 in Vietnam; June 2021 in Nigeria), and all interventions ended at the same time (July 2021 in Vietnam; October 2021 in Nigeria). All three interventions targeted consumers and FV vendors within the selected study neighbourhoods. Therefore, all respondents could have been potentially exposed to the intervention at the vendor level and the promotional campaigns. In contrast, the coupon system followed a randomized control trial design with part of the respondents receiving the intervention (coupons) and others not (control group).

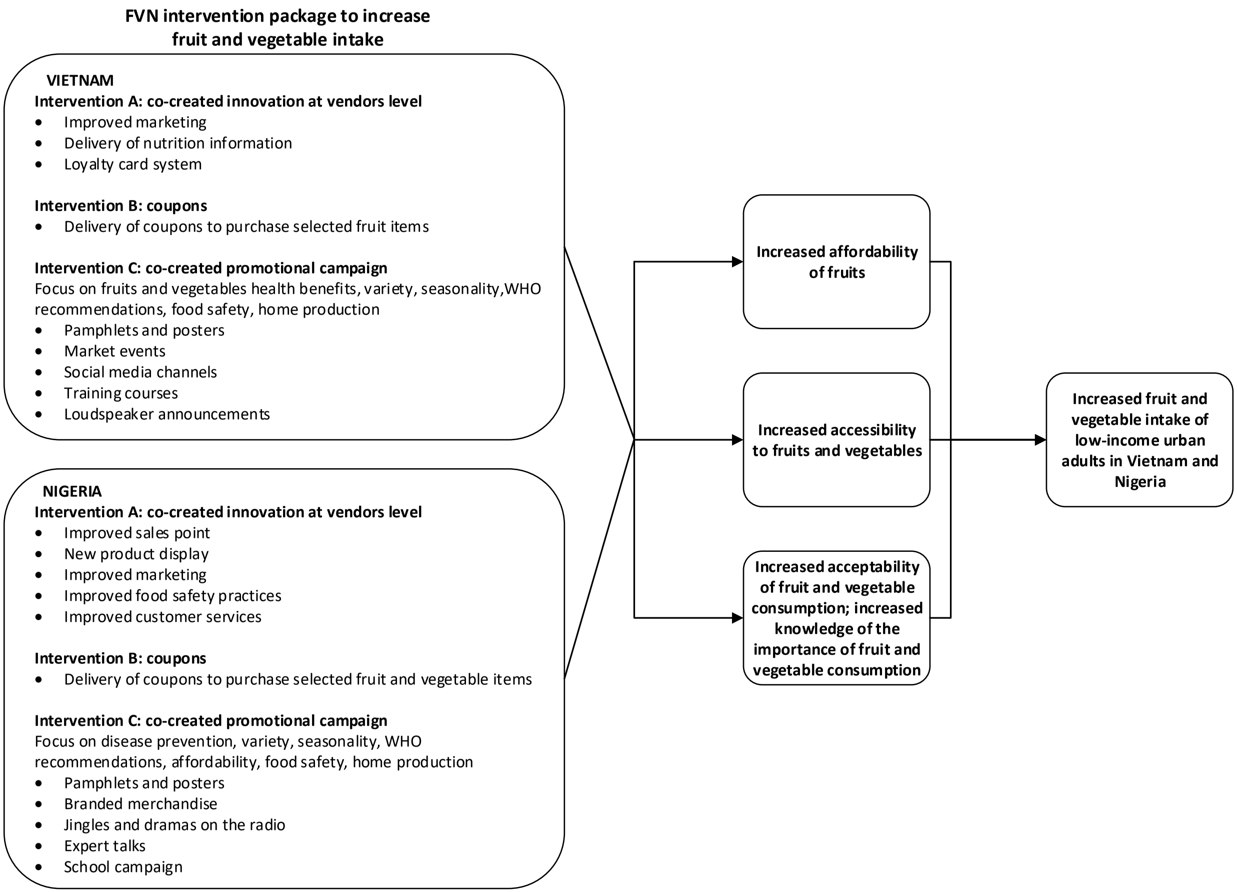

Figure 5.1. Overview of "Fruit and Vegetable intake in Vietnam and Nigeria" (FVN) project interventions and pathway for increasing fruit and vegetable intake of low-income urban Vietnamese and Nigerian study population.

Dietary and exposure assessment

In both countries, a repeated quantitative multi-pass 24-hour recall (24hR) (33) was administered by trained local interviewers to obtain information on food consumption. For each respondent, two non-consecutive 24hRs were collected with at least two days and at most one month in between interviews. Description and quantities of all foods and drinks consumed by the participant in and outside of the home in the previous 24 hours were recorded. Interviewers also recorded the time of day of the eating episode, the place of preparation, the frequency of consumption and the place of purchase of each ingredient. Additionally, a questionnaire was administrated using KoboToolbox (KoboToolbox Inc.) software to obtain information on the exposure to the interventions. Information on the exposure to interventions A and C was self-reported by respondents, while exposure to intervention B was based on the random allocation to the coupon system. Finally, the respondent's weight and height were measured twice using a scale (Tanita in Vietnam; SECA 813 in Nigeria) and stadiometer (SECA 213 in both countries) following standard methods (34). From the mean of the two measurements, body mass index (BMI) was calculated as indicators of underweight (BMI <18.5 kg/m^2), normal range (BMI 18-24.99 kg/m^2) and overweight/obesity (BMI ≥25 kg/m^2) (34). The FVN project preparation started in 2019 and some delays occurred due to the COVID-19 pandemic. As for endline assessment, data were collected between October-December 2021 in Vietnam and November-December 2021 in Nigeria. In Vietnam, data collection took place three months after the end of the implementation of the FVN interventions because of restrictions on home visits imposed by the government due to the COVID-19 pandemic. In Nigeria data was collected immediately after the end of the FVN interventions.

Data processing and analysis

Data from the 24hR interviews were checked for missing values, inconsistencies, and extreme high and low intakes. From these, information on FV intakes was extracted for the aim of this study. From each recall, daily FV intakes were calculated by multiplying the quantity recorded in each 24hR by the weekly frequency of consumption and divided by seven days. Then the average of the two recalls was calculated and used for analysis. For each country, descriptive statistics were used to explore the sociodemographic characteristics of the exposed and control groups.

Mixed models were used to compare intakes of total FV, and fruits and vegetables separately, between the exposure group and the control group, and to explore the impact of the degree of exposure on these outcomes. For the former, intention-to-treat analysis was performed, considering all respondents from the exposed areas as exposed to the interventions. Additionally, trend analysis was performed to explore the hypothesis of an ordered increase of total FV intake, and fruit intake and vegetable intake separately across the degree of exposure to the different interventions in the exposed groups. As the study populations included females and males living in the same households a random effect for household was included in the mixed model. Bootstrapping was applied for standard error estimation as some outcomes were skewed. All models were adjusted for age, sex, neighbourhood, BMI, household size, education, and occupation. Furthermore, fruit intake analyses were repeated after ranking fruit intakes instead of using actual amounts consumed. Sensitivity analysis was also performed to check the contribution of outliers for high intakes (>95% of the distribution). Since no differences were found with and without ranking, and with and without outliers, all observed data points were included in the final analyses. Effect modification by sex was investigated by adding an interaction term to the models. We performed all analyses in SPSS Statistics (version 28.0.1.1) (35).

RESULTS

In Vietnam, the exposed group (n=283) included more females (70%) compared to the control group (n=299; 60% females) and the average age was 38 years for both groups (Table 5.1). Most of the exposed respondents were skilled employed (38%), while the majority of the control group was unskilled (45%). Although education level differed between the groups, more than half of the respondents finished high school in both groups (60% exposed; 62% control) and the majority had a normal BMI (80% exposed; 86% control). Among the exposed group, 54% of the respondents reported having received loyalty cards or nutrition advice from the fruit and vegetable vendors (intervention A); 72% received the coupons to purchase fruits (intervention B); and only 31% reported being exposed to the promotional campaigns on the importance of daily fruit and vegetable consumption (intervention C). Overall, among the study participants, 14%, 34% and 29% were exposed to one, two and three interventions respectively and 22% were not exposed to interventions at all.

In Nigeria, the exposed (n=291) and the control group (n=335) were comparable regarding the proportion of females, participants from urban areas (68% and 64% females, 47% and 49% urban), average age (38 ± 8.1 years exposed; 37 ± 7.7 years control) and in both groups 39% were overweight/obese (Table 5.1). Respondents in the exposed group lived in larger households, composed on average of 6 ± 1.7 members, compared to respondents in the control group (5 ± 1.7 members). Although they differed in occupation and education, a large proportion of the respondents in both groups ran their own business (65% exposed; 54% control) and finished secondary school (41% exposed; 52% control). Almost all respondents (92%) reported having noticed the new display, aprons and umbrellas or the improved hygienic practices of the fruit and vegetable vendors (intervention A); or have received the coupons to purchase fruit and vegetable (88%) (intervention B); and 70% were exposed to at least one of the activities implemented to increase awareness on the importance of daily fruit and vegetable consumption (intervention C). All respondents reported having been exposed to at least one intervention, more than half were exposed to all three interventions (58%), one-third to two interventions (34%) and only 8% of the respondents to one intervention.

Table 5.1 General characteristics of the Vietnamese and Nigerian study population by exposure to the interventions of the FVN project.

	Vietnam			Nigeria		
	Exposed (n = 283)	**Control (n=299)**	**p-value**	**Exposed (n=291)**	**Control (n=335)**	**p-value**
Female, %	69.6	60.2	.013	67.7	64.2	.273
Urban, %	53.7	53.2	.931	47.4	49.0	.679
Age, mean (sd)	37.9 (7.2)	37.6 (7.3)	.956	38.1 (8.1)	37.3 (7.7)	.360
Household size, mean (sd)	4.9 (1.3)	4.3 (1.2)	.240	5.6 (2.0)	5.2 (1.6)	<.001
Occupation, %			<.001			<.001
Skilled employment	38.5	38.8		16.8	19.1	
Unskilled employment	31.1	45.2		3.4	6.9	
Own business	20.5	9.0		64.6	53.7	
Unemployed	9.9	7.0		15.1	20.3	
Education, %			<.001			<.001
No education	1.1	0		4.5	3.6	
Primary school	7.8	2.3		27.8	19.4	
Secondary school	17.0	20.4		41.2	51.6	
High school	60.4	61.9		22.7	26.9	
Above high school	13.8	15.4		3.8	1.8	
BMI, mean (sd)	21.8 (2.7)	22.0 (2.5)	.335	24.6 (5.2)	24.7 (5.5)	.702
Underweight, %	8.0	4.7		7.1	3.9	
Overweight/obesity, %	11.5	9.6		38.6	39.0	
Fruit and vegetable intake >400 g/d, %	56.6	58.8	.596	49.2	25.3	<.001
Fruit and vegetable intake, g/d						
Mean (sd)	451 (167)	442 (139)		445 (311)	297 (222)	
Median (iqr)	421 (208)	430 (165)		390 (419)	238 (272)	
Fruit intake, g/d						
Mean (sd)	167 (126)	145 (99)		283 (269)	143 (184)	
Median (iqr)	145 (135)	129 (113)		230 (372)	80 (215)	
Vegetable intake, g/d						
Mean (sd)	284 (108)	296 (106)		162 (107)	154 (103)	
Median (iqr)	268 (148)	285 (134)		133 (119)	130 (107)	
Exposure, %						
Intervention A	54.0			92.4		
Intervention B	72.0			87.6		
Intervention C	31.0			69.1		
1 intervention	14.3			8.1		
2 interventions	34.3			34.2		
3 interventions	29.0			57.6		
Not exposed	22.4			0		

p-value, exposed compared to control; sd = standard deviation; BMI = Body Mass Index; Underweight: BMI <18.5; Normal range : BMI 18.5 – 24.99; Overweight/obesity: BMI ≥ 25; g/d = grams per day; iqr = interquartile range; all exposure are self-reported except to intervention B based on random allocation; A = intervention at vendor level; B = coupon system intervention; C = promotional campaign intervention; 1 = exposed to one intervention, 2 = exposed to two interventions; 3 = exposed to 3 interventions.

Adjusted mixed model for comparison between exposed and control group

More than half of the Vietnamese population met the daily global recommendations for FV intake (57% exposed; 59% control) with an average intake of 451 g/d and 442 g/d, respectively (Table 5.1). The unadjusted results for both countries are reported in the supplementary materials (Tables S5.2). After adjustment, the two groups had comparable total daily FV intake (difference (exposure minus control) 15.8 g/d, 95%CI -3, 31) (Table 5.2). The exposed group had higher intake of fruit compared to the control group (difference 24.2 g/d, 95%CI 11.8, 34), while vegetable intake was comparable between the groups (difference -8.6 g/d, 95%CI -21, 4). No significant interaction between sex and exposure to the interventions was found (Supplementary materials Table S5.3). However, for fruit intake stratified analysis showed a difference of 21.4 g/d (95%CI 1, 46) for females and 14.2 (95%CI -14, 44) for males, compared to the control group (supplementary materials Table S5.4).

In Nigeria, a higher proportion of exposed respondents met the daily recommendation for FV consumption compared to the control group (49% exposed; 25% control) (Table 5.1) with an average intake of 445g/d and 297g/d, respectively. The exposed group consumed considerably higher amounts of total FV (difference 169 g/d, 95%CI 132, 205) compared to the control group (Table 5.2). The difference was mainly due to higher fruit intake (difference 156 g/d, 95%CI 122, 193); but a small difference was found also in vegetable intake between groups (difference 11.8 g/d, 95%CI -2, 26). No evidence of effect modification by sex was observed (Supplementary materials Table S5.5).

Table 5.2 Comparison of fruit and vegetable consumption (g/d) between exposed and control groups of the FVN project.

	Vietnam (n=582)					**Nigeria** (n=626)				
	Estimate	*SE*	*95% CI*		*p*	*Estimate*	*SE*	*95% CI*		*p*
Fruits and vegetables	15.8	10.0	-2.6	31.1	.073	169.3	19.4	131.8	204.9	<.001
Fruits	24.2	7.1	11.8	34.2	<.001	156.5	17.2	121.7	193.0	<.001
Vegetables	-8.6	6.6	-21.3	3.5	.130	11.8	6.8	-2.4	26.2	.030

Control group set as reference. Mixed model adjusted for age, sex, area, education, occupation, BMI, household size; household included as random factor; SE = standard error; CI = confidence interval; SE and p-values from bootstrapping.

Fruit and vegetable consumption across degree of intervention exposure

We did not find any strong association between the degree of exposure to the interventions and FV intakes (Table 5.3). Compared to being exposed to 3 interventions, Vietnamese respondents not exposed to any intervention or exposed to 1 or 2 intervention(s) had only slightly lower intakes of total FV, or fruit intake and vegetable intake separately, with all confidence intervals including the null. The p-values for linear trend suggests that there is no evidence of a dose-response relations between the amount of intervention exposure to and intakes of fruits and/or vegetables. Nigerian respondents exposed to 1 or 2 interventions had relatively lower intakes compared to respondents exposed to all 3 interventions (Table 5.3). The largest differences from the maximum exposure were found in the group with the lowest degree of exposure for total FV (difference -127 g/d, 95%CI -370, 280) and fruit (difference -117 g/d, 95%CI -272, 81) intakes; the accompanying p-values for linear trend suggest a trend for fruit intake across the exposure groups (p=0.08).

Table 5.3 Comparison fruit and vegetable consumption (g/d) across exposure to interventions in the Vietnamese and Nigerian study populations

	Vietnam (n=582)					**Nigeria** (n=626)				
	Estimate	*SE*	*95% CI*		*p*	*Estimate*	*SE*	*95% CI*		*p*
Fruit and vegetable										
Not Exposed	-44.6	39.7	-127.7	47.3	.333	NA				
Exposed to 1 intervention	-22.9	31.1	-94.0	43.8	.568	-127.2	84.4	-370.4	280.5	.197
Exposed to 2 interventions	-28.3	31.1	-98.8	60.1	.453	-47.6	59.8	-155.3	37.9	.408
p trend					.459					.146
Fruit										
Not Exposed	-34.1	33.4	-103.0	30.5	.356	NA				
Exposed to 1 intervention	-24.0	21.9	-66.2	18.1	.377	-117.9	70.3	-271.9	80.8	.114
Exposed to 2 interventions	-26.5	22.3	-87.6	60.2	.395	-42.2	50.2	-127.5	10.7	.375
p trend					.358					.082
Vegetable										
Not Exposed	-6.5	30.5	-79.8	67.0	.868	NA				
Exposed to 1 intervention	1.6	18.8	-44.1	42.4	.946	-19.8	23.1	-271.9	80.8	.688
Exposed to 2 interventions	-7.2	16.8	-42.0	32.8	.737	-4.2	16.2	-39.8	43.6	.782
p trend					.986					.655

Exposed to 3 interventions (maximum) as reference; mixed model adjusted for age, sex, area, education, occupation, BMI, household size. Household included as random factor, and bootstrap applied; SE = standard error; CI = confidence interval; SE and p-values from bootstrapping; NA = not applicable, all Nigerian respondents reported to be exposed to at least one intervention.

DISCUSSION

This study evaluated the potential impact of an integrated nutrition-sensitive project on FV consumption among low-income adults in urban and peri-urban areas in Hanoi, Vietnam, and Ibadan, Nigeria. In Nigeria, subjects living in the intervention areas had higher total FV intake compared to a group from the control area. The Nigerian exposed group consumed particularly more fruits compared to the control group rather than vegetables. In Vietnam, the exposed group consumed slightly more fruits but not more vegetables compared to the control group, and the difference in fruit was not large. Moreover, in our additional exploratory analysis, we could not determine a clear dose-response relationship of exposure to multiple interventions since we found a slight but not significant positive trend on fruit and/or vegetable intake in Nigeria but not in Vietnam.

Higher fruit consumption among subjects from the intervention areas was as expected consistent with our study hypothesis. The coupon intervention, in both countries, and the intervention at vendor level in Vietnam, addressed accessibility and affordability of mainly fruits rather than vegetables. A previous study showed that the affordability of fruits in Vietnam and of FV in Nigeria was one of the main barriers to consumption faced by our study populations (32). In line with other studies, lack of financial means is one of the main drivers of low FV consumption (36), unhealthy diets and food choices in poor-resource settings (37–39). On the other hand, affordability seemed not to be an issue for vegetable consumption in our Vietnamese setting, contrary to Nigeria. A possible explanation is that seasonal vegetables are inexpensive even for low-income populations in Vietnam, hence cheap vegetables are affordable all year round. In addition, in general, price-elasticity is lower for vegetables compared to fruits (40) and purchase of vegetables is less prone to price fluctuations.

The provision of food vouchers to purchase specific nutritious food items is an effective social protection intervention at food system level aiming to improve diet quality and nutritional status (41). It provides a dual effect compared to cash transfers: a direct price discount on the specific food item; and indirect information and advertisement of the product (42,43). Overall, controlling food prices at the market level and designing social assistance policies tailored for urban contexts may support a sustained higher intake of FV for our study low-income urban populations (44).

In Vietnam we found a weak indication of gender differences, with a larger difference between exposed and not-exposed areas in women than in men. This may be supported by results from a focus group discussion with the study population where fruits were reported to be perceived by men as “women’s food” (45). However, the difference between women and men was small, and need to be explored more extensively in future studies.

Our data on dietary intakes were collected after the end of the FVN interventions, hence solely a lasting effect on the study population could have been measured. In particular, the small differences between groups found in Vietnam could have been diluted, because dietary intakes were assessed three months after the end of the project. Moreover, the period of intervention implementation was characterized by instability at market level and restrictions related to shopping practices due to the COVD-19 pandemic. This could have limited the exposure to the interventions implemented at the markets and the purchase of fresh products due to the restricted mobility. This was especially the case in Vietnam, where dietary intake data were collected immediately after the end of a strict lockdown. Hence, the observed differences between the exposed areas and control may have been reduced.

In addition, the lack of difference in vegetable consumption across the groups in both countries may be due to an inherent difficulty in increasing the amount of vegetable consumption. Although consumed in low amounts, most of our study participants consume vegetables regularly (99% in Vietnam; 95% in Nigeria), in contrast to fruits, which were consumed by a lower percentage of the population (70% in Vietnam; 45% in Nigeria). Vegetables are part of the traditional diets and are consumed in meals and dishes in combination with other foods. Increasing vegetable consumption might also require increasing intake of these other foods in the dishes. We did not observe such an increase, as additional analyses showed that the consumption of all other food groups was similar between exposed and control groups. Fruits are often consumed in between meals or as snacks, and as such the intake of fruits could be increased independent of other foods consumed.

In general, out-of-home consumption practices need to be taken into account since this could limit the possibility to increase the amount of vegetables included in the recipes. A previous study conducted in Ibadan, reported an increased rate of urban out-of-home consumption in the last decades, and includes a variety of traditional, processed and unprocessed foods (46), and it is driven by mobility practices and distance to work (47). Changing recipes, may be difficult but the introduction of new recipes were found effective in increasing vegetable consumption in Nigeria (48). This is also confirmed by the reported desire of buying more fruits, expressed by our study populations during the assessment conducted before the development of the interventions (49,50).

Our additional dose-response explorative analyses suggest that FV intake of the exposed population might be higher when exposed to multiple interventions compared to fewer interventions, especially in Nigeria. Previous studies support the importance of a combination of multi-sectorial and integrated approaches to increase diet quality (51) and FV consumption (52), since several factors affect the diets and consumer choices. Our food system approach targeting different agents (consumers and vendors) allowed us to develop a comprehensive project. The three distinct interventions were interrelated and connected and addressed drivers of consumption at the same time with different approaches to complement and reinforce each other. However, attributing the effect on the combination of interventions is difficult because the study design does not allow for robust analysis. Exposure was self-reported as it was impossible to assess the actual exposure to the interventions among FV vendors and to the promotional campaign. Respondents could have been unaware of being exposed to the nudges at vendors or market events which leads to an underestimation of reported exposure (53).

We used a quasi-observational design to evaluate the FVN project. The study design does not allow us to attribute the found effect on FV consumption solely to the interventions. Respondents in the exposed and control areas could have differed in baseline FV intakes, and the differences in education and occupation in both countries could be an indicator of difference in socioeconomic status between the groups. However, we adjusted for these covariates in our analyses and hence confounding by these factors was minimised. Furthermore, we did not account for potential differences in food environment between the neighbourhoods, hence residual confounding cannot be excluded. Regarding the implementation of the interventions, it should be noted that social limitations imposed to limit the spread of COVID-19 pandemic could have affected availability of and accessibility to fresh foods, which we were not able to anticipate and control for. Lastly, eight months of intervention implementation might not have been sufficient to have an impact in the study settings, as prolonged exposures to multisectoral nutrition-sensitive interventions are shown to be more successful (25).

To conclude, combined interventions at food system level may offer a potential to increase in FV consumption. Co-creation methods can be applied across countries, but the differences found between Vietnam and Nigeria highlighted the importance of context sensitivity. Evaluation of the interventions can add further insights on the impact of the project.

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SUPPLEMENTARY MATERIALS

Table S5.1 Building selection criteria for Ibadan, Nigeria

	Low income	Non-low income
Type of roof material	corrugated	non-corrugated
Type of fence	partially fenced no fence	fully fenced
Wall plaster	partially plastered no plaster	fully plastered

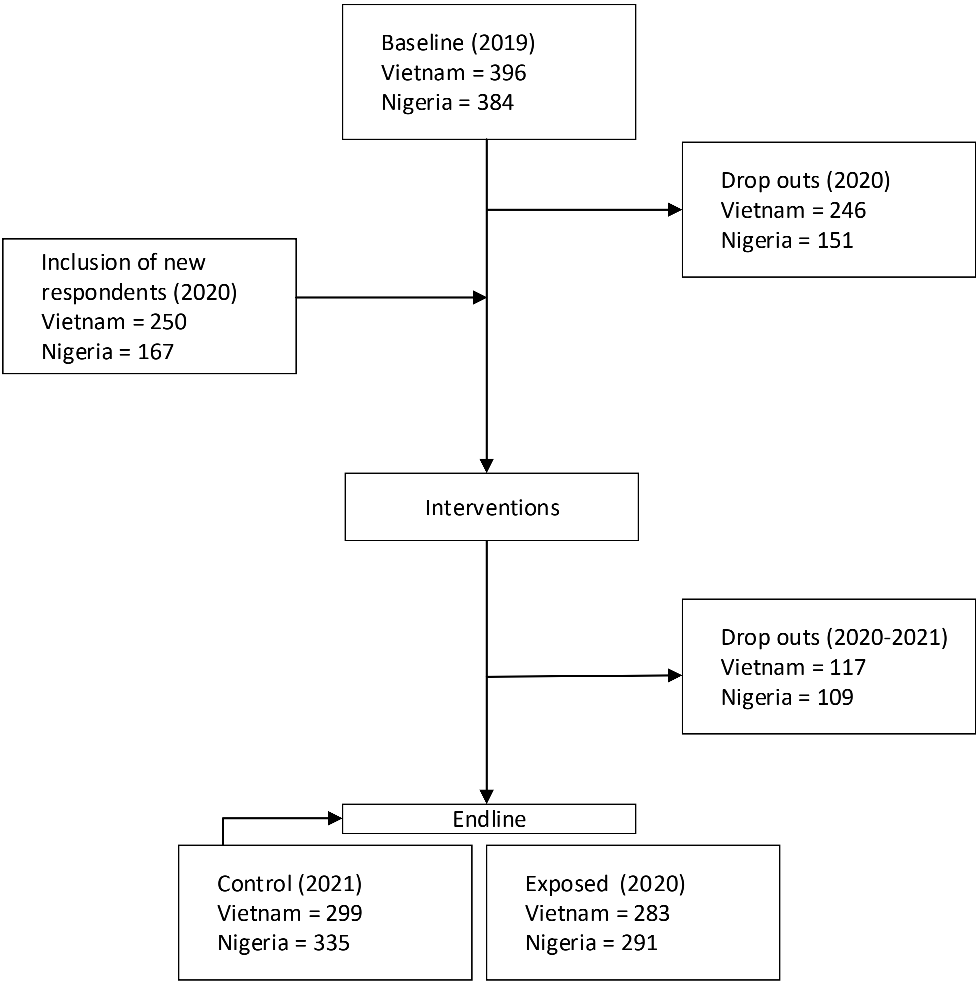

Figure S5.1 Flow chart of population selection.

Table S5.2 Comparison of fruit and vegetable consumption (g/d) between exposed and control groups

	Vietnam (n=582)					Nigeria (n=626)				
	Estimate	*SE*	*95% CI*		*p*	*Estimate*	*SE*	*95% CI*		*p*
Model[1]										
Fruits and vegetables	14.6	10.0	-3.6	30.1	.094	165.7	19.7	125.4	209.0	<.001
Fruits	23.5	7.1	10.8	33.6	<.001	153.5	16.9	117.5	188.9	<.001
Vegetables	-9.1	6.7	-21.9	3.2	.113	11.4	6.8	-2.7	26.9	.048
Model[2]										
Fruits and vegetables	14.6	10.0	-2.6	29.8	.087	165.7	19.8	125.4	207.3	<.001
Fruits	23.5	7.2	10.1	34.8	<.001	153.5	17.0	118.0	190.7	<.001
Vegetables	-9.1	6.6	-21.3	2.6	.110	11.4	6.8	-2.0	25.1	.036
Model[3]										
Fruits and vegetables	14.6	10.0	-4.2	31.2	.097	165.7	19.6	126.5	206.1	<.001
Fruits	23.5	7.2	10.4	34.4	<.001	153.5	17.5	118.4	190.0	<.001
Vegetables	-9.1	6.5	-21.5	1.8	.109	11.4	7.0	-3.0	25.5	.039
Model[4]										
Fruits and vegetables	14.6	9.9	-3.7	30.0	.085	165.7	19.6	124.8	204.8	<.001
Fruits	23.5	7.1	10.5	34.6	<.001	153.5	17.1	116.3	192.4	<.001
Vegetables	-9.1	6.4	-20.9	2.5	.102	11.4	6.8	-2.2	25.5	.041
Model[5]										
Fruits and vegetables	14.6	10.1	-3.2	30.2	.093	165.7	19.5	124.6	205.8	<.001
Fruits	23.5	7.0	10.2	33.8	<.001	153.5	17.2	117.8	190.7	<.001
Vegetables	-9.1	6.5	-22.2	2.8	.109	11.8	6.9	-2.7	25.2	.041
Model[6]										
Fruits and vegetables	14.6	10.0	-2.5	29.4	.086	165.7	19.5	126.2	205.6	<.001
Fruits	23.5	7.2	10.4	34.4	<.001	153.5	17.6	116.0	193.7	<.001
Vegetables	-9.1	6.5	-21.5	1.8	.109	11.4	7.0	-3.1	25.7	.046
Model[7]										
Fruits and vegetables	14.6	9.9	-3.7	30.0	.085	165.7	19.4	124.3	206.5	<.001
Fruits	23.5	7.1	10.5	34.6	<.001	153.5	17.4	115.0	195.5	<.001
Vegetables	-9.1	6.4	-20.9	2.5	.102	11.4	6.8	-1.8	25.2	0.35
Model[8]										
Fruits and vegetables	15.8	10.0	-2.6	31.1	.073	169.3	19.4	131.8	204.9	<.001
Fruits	24.2	7.1	11.8	34.2	<.001	156.5	17.2	121.7	193.0	<.001
Vegetables	-8.6	6.6	-21.3	3.5	.130	11.8	6.8	-2.4	26.2	.030

Control group set as reference. SE = standard error; CI = confidence interval; [1] model not adjusted for covariates; [2] model adjusted for sex; [3] model adjusted for sex, neighborhood; [4] model adjusted for sex, neighborhood, age; [5] model adjusted for sex, neighborhood, age, household size; [6] model adjusted for sex, neighborhood, age, household size, occupation; [7] model adjusted for sex, neighborhood, age, household size, occupation, education; [8] model adjusted for sex, neighborhood, age, household size, occupation, education, BMI.

Table S5.3 Difference in intake of total fruits and vegetables, and fruits and vegetables separately between exposed and control group by gender in the Vietnamese population.

	Vietnam (n = 582)				
	Estimate	*SE*	*95%CI*		*p*
Fruits and vegetables					
Exposed	2.9	20.5	-38.2	43.7	.882
Females	4.8	16.7	-27.2	35.5	.770
Exposed * Females	11.7	27.2	-43.1	66.0	.668
Fruits					
Exposed	14.2	14.6	-12.6	44.5	.336
Females	19.8	11.7	-3.6	43.6	.087
Exposed * Females	7.1	19.0	-32.2	43.6	.701
Vegetables					
Exposed	-11.4	15.6	-44.2	18.9	.473
Females	-15.0	12.6	-41.1	9.7	.239
Exposed * Females	4.6	19.5	-33.2	43.5	.816

Control group and males set as reference. Mixed model adjusted for age, area, education, occupation, BMI, household size; SE = standard error; CI = confidence interval

Table S5.4 Difference in intake of fruits between exposed and control group stratified by sex in the Vietnamese population.

	Vietnam (n = 582)				
	Estimate	*SE*	*95%CI*		*p*
Females					
Exposed	21.4	12.5	-1.0	46.1	.088
Males					
Exposed	14.2	14.8	-13.8	44.4	.341

Control group and males set as reference. Mixed model adjusted for age, area, education, occupation, BMI, household size; SE = standard error; CI = confidence interval

Table S5.5 Difference in intake of total fruits and vegetables, and fruits and vegetables separately between exposed and control group by sex in the Nigerian population.

	Nigeria (n = 626)				
	Estimate	*SE*	*95%CI*		*p*
Fruits and vegetables					
Exposed	124.3	44.0	43.0	205.2	.004
Females	-3.2	28.5	-60.2	49.5	.908
Exposed * Females	60.4	52.3	-45.2	168.6	.248
Fruits					
Exposed	120.6	36.8	53.4	189.4	<.001
Females	9.1	24.3	-44.5	56.8	.734
Exposed * Females	48.9	45.2	-39.4	135.1	.292
Vegetables					
Exposed	3.7	15.8	-25.8	36.6	.824
Females	-12.3	12.0	-36.4	11.1	.302
Exposed * Females	11.54	18.9	-28.0	48.9	.537

Control group and males set as reference. Mixed model adjusted for age, area, education, occupation, BMI, household size; SE = standard error; CI = confidence interval

5

Chapter 6

General discussion

Accessibility, affordability and acceptability of fruits and vegetables (FV) in low-income urban populations are among the important drivers of FV consumption that need to be targeted to improve diet quality for all. In this thesis we made an effort to generate knowledge on effective strategies to monitor and increase FV consumption through an integrated nutrition-sensitive project at the food system level addressing these drivers in low- and middle-income countries (LMICs), using Vietnam and Nigeria as case studies. We identified key insights through diet evaluation, analysis of consumption trends, and effect evaluation of the project.

Main findings

The identification of dietary patterns showed that different consumption patterns coexist within the low-income urban Vietnamese and Nigerian populations (Chapter 2). In each study population, three dietary patterns were identified, each pattern differing in diet quality and food quantities consumed. Dietary patterns characterized by high vegetable consumption were the healthiest, and also included the highest amounts of other foods. All observed patterns included unhealthy foods such as high quantities of processed and red meat in Vietnam and sugar sweetened products in Nigeria. In Vietnam, the consumers of each pattern differed by age, area of residence, household size, marital status, education, occupation and living standard. In the Nigerian study population, the sociodemographic characteristics across dietary patterns were comparable. The identification and characterisation of consumer segments and their dietary patterns is important to tailor interventions and address specific needs.

Results from the validation study suggest that the fruit and vegetable component of the Global Dietary Recommendations score (FV-GDR) is a promising indicator to assess FV intakes at the population level (Chapter 3). The FV-GDR estimates total FV intake well, but the intakes of specific FV food groups are captured to lesser extent. Observed quantities consumed correlate positively with the FV-GDR, but a cut-off for adequacy (intakes ≥400 g/d) resulted in country-specific value, a topic which requires further study.

When monitoring FV intakes of women over the FVN intervention period, FV diversity remained stable with a slight increase over time (Chapter 4). Consumption of specific FV groups fluctuated over time, indicating that consumption and availability are probably driven by seasonality. Therefore, as FV from all subgroups are not all available at the same time, this impact the possibility to increase consumption of diverse FV.

The end-line effect evaluation of the FVN project showed a higher intake of fruit in the study population exposed to the interventions compared to a study population recruited from the control area, both in Vietnam and Nigeria, and a higher total FV intake in Nigeria only (Chapter 5). The evaluation also suggests that individuals consumed slightly more FV when exposed to more interventions at the same time. This association was stronger in Nigeria than in Vietnam.

Effect of the FVN project on fruit and vegetable consumption

The findings that respondents from the intervention areas had higher intakes of especially fruits but also vegetables compared to the respondents in the control areas (Chapter 5) suggest that the project had a positive impact on consumption. Although it is difficult to attribute the observed results directly to the project because the study design does not allow to investigate causality (see below), supporting pieces of evidence sustains the likelihood of this causality.

First, although not reported in this thesis, the single interventions showed positive effects on intermediate outcomes that could have led to increased consumption. The evaluation of intervention A (FV vendors), found that retailers successfully implemented the interventions in both countries, reporting high satisfaction for all types of activities implemented, with the exception of only one activity in Nigeria, the "combination pack", which was less liked (1). Regarding intervention B (coupon system), results from the randomized controlled trial showed that the majority of the respondents who received the coupons to purchase selected fruits, used them in both countries (70% in Vietnam; 80% in Nigeria) (2). A lasting effect on consumption was also found in the Vietnamese population but not in the Nigerian population. The evaluation of intervention C (promotional campaign) showed consumers were reached who indicated a perceived increase in knowledge and intention to consume more FV in both countries. In Vietnam, a moderate reach of the campaign was found but respondents increased their perception of the importance of consuming FV compared to baseline. Additionally, their knowledge of the recommended intakes and health benefits improved and inspired them to increase their FV consumption (3). In Nigeria, the reach of the promotional campaign of intervention C was large and respondents reported that it influenced the consumption of FV (4). The perceived importance of daily fruit consumption and of different varieties as well as the new knowledge about the health benefits increased after the intervention and inspired the respondents to consume them more. This suggests that the three interventions addressed the right determinants of consumption, could reach the target population and influenced their willingness to consume FV.

Secondly, we were able to perform a baseline-end-line comparison of FV intakes for a limited and selected sample of the population exposed to the FVN project. In Vietnam, consumption of total FV, and fruits and vegetables separately were higher at end-line compared to baseline (Box 5.1). In Nigeria, only fruit intake and total FV intake increased after exposure to the FVN interventions. Despite the limitation of a small sample size, the selected study population and the analysis being preliminary, these results also support the likelihood the project had a positive effect on FV intake of the study population.

Lastly, as part of the evaluation of the FVN project (Chapter 4), the monitoring study suggested a modest increase of the population consuming FV and a slight increase of variety and diversity of consumption. As the indicator used was correlated with the amount of intake of FV (Chapter 3), we may assume these results also indicate a slight increase in amount consumed during the FVN intervention.

Using the principle of triangulation (5), the evaluation of the single interventions, the results of the evaluation study, the monitoring study and the baseline-end-line evaluation makes it likely that the strategies used in the FVN project are effective in increasing FV consumption.
However, methodological issues and limitations of our study should be acknowledged and these and their influence on study results are further discussed below.

Box 6.1 Preliminary results baseline-end-line comparison for Vietnam and Nigeria

The comparison of fruits and vegetable intakes was performed for respondents with baseline (2019) and end-line (2021) assessments. The reported results are medians [interquartile range].
In Vietnam, the comparison was performed for 150 respondents. Intakes of fruits and vegetables increased: fruits from 63g [0-378] to 171g [0-407]; vegetables from 204g [51-458] to 268g [75-543]; and fruits and vegetables from 321g [53-757] to 443g [75-853]. None of the results were statistically significant.
In Nigeria, the comparison was performed for 233 respondents. Intakes of fruits and total fruits and vegetables significantly increased: fruits from 0g [0-74] to 210g [0-845]; fruits and vegetables from 79g [35-245] to 360g [0-1268]. Vegetable intake[1] decreased from 59g [0-111] to 41g [0-78].

[1]For this comparison intakes of tomato, sweet pepper and onion were excluded from both assessments for differences in data collection.

A posteriori dietary pattern analysis generates nuances hidden by a priori dietary quality scores

Dietary pattern analysis presents an alternative and holistic approach to evaluate the complexity of the human diet (6). It reflects dietary choices and preferences and takes the interaction between dietary components into account. Diverse dietary patterns and food choices were found in the low-income population living in urban and peri-urban areas of Hanoi, Vietnam, and Ibadan, Nigeria (Chapter 2).

Dietary patterns analysis can generally be classified into *a priori* or *a posteriori* methods. *A priori* methods include for instance scores and indexes based on and limited to the current knowledge about the association between diets and specific health outcomes or diseases (7). Examples are the Healthy Eating Index (HEI) (8) and the Minimum Dietary Diversity Score for Women (MDDS-W) (9). They focus on healthy and unhealthy foods or food groups and are often based on adherence to existing dietary guidelines. These methods are important for monitoring the overall quality of the diet, evaluating the effects of dietary interventions and validating dietary recommendations (10). They are simple to compute and compare, and easy to use in large populations, as we also found in Chapter 3.

The *a posteriori* methods are data-driven and consist of statistical approaches that derive dietary patterns from observed data (11). These methods include several statistical procedures such as Principal Component Analysis (PCA) and Latent Class Analysis (LCA). PCA is based on the associations between dietary variables and is generally used to reduce the number of variables measured to identify a complex domain into a limited number (12). It attributes new uncorrelated values to each variable that are linear functions of those observed and uses them to identify features, in this case dietary patterns. LCA is based on individual differences in dietary components (13) and allocates individuals in a single cluster meaning that each respondent belongs to one single dietary pattern (14).

LCA allowed us to describe prevailing and distinct dietary patterns. As LCA identifies class memberships and relates them to explanatory variables, it allowed us to characterise the consumers of the identified dietary patterns in terms of consumption behaviours, diet quality, and sociodemographic determinants (15). In this way, subpopulations, vulnerable groups, and populations with specific needs can be identified, LCA being a relevant tool for the public health nutrition field. The comprehensive approach of LCA, which includes the interaction of dietary components and allocation of individuals in specific patterns based on the assumption of latent factors underlying the observed variables, can help in identifying gaps, setting priorities, and developing and tailoring nutrition interventions and policies. Tailoring interventions to specific dietary patterns and addressing the specific needs of those consuming these patterns would increase the compliance, impact and cost-effectiveness of interventions and projects (16).

Another advantage of this comprehensive approach is that dietary patterns are more understandable to the general population. Since they represent the actual consumption habits, consumers can relate to them. This facilitates the translation into practical interventions or even dietary guidelines (6). Furthermore, the allocation of consumers in nonoverlapping patterns supports further investigation and analysis of the association with other health outcomes or determinants of consumption (17). Linking dietary patterns to health determinants is relevant for integrating nutrition into a broader perspective of public health. Moreover, since *a posteriori* methods go beyond the dichotomisation of healthy and unhealthy, and are not limited to pre-existing scientific knowledge, they are promising for the development of nutrition research by opening possible new insights into dietary behaviours, food choices and health outcomes.

However, this method does not come without limitations. The patterns found are not always clearly recognizable and therefore more effort is required for the interpretation and further investigation of the context and drivers of consumption (14). Moreover, LCA, likes other *a posteriori* methods, introduces subjectivity that needs to be considered in the evaluation of the findings. The various decisions that the researcher needs to make during LCA analysis can have an impact on the interpretation and reproducibility of the results (13). These include the selection of dietary variables, the number of patterns to focus on, and the interpretation of them including the identification of the characteristics and differences between patterns. Other researchers could make other decision on the selection of the best model, based on their understanding of the context and background information. In Chapter 2, we selected three dietary patterns based on model parameters but also on plausibility based on our knowledge of the local context. We also decided to categorize the intakes based on the percentage of non-consumers. Selection of a different number of patterns and different variable categorizations may identify or miss other nuances of the population. Furthermore, the names assigned to the patterns are the choice of the researcher and can be differently interpreted. For this reason, we decided to name the patterns found in our study based on the food groups that differed the most between patterns.

It is, therefore, mandatory to be transparent on the rationale behind each choice to evaluate the quality of the studies and to arrive at a robust method. On the other hand, these decisions provide the possibility to include context-specific factors. For instance, we created the food groups adapting the food groups of the Dietary Quality Questionnaire (DQQ) based on local knowledge. In Vietnam we split rice and rice products from the other grains and tubers because of the common consumption of the former and low consumption of tubers; while in Nigeria we divided grains from tubers because tubers are commonly consumed. For the same reason, we created different subgroups of the meat food group in Vietnam, since red meat from non-ruminant (mainly pork) is highly consumed. In both countries, we merged all types of fruits into a single group due to the low consumption of each subgroup. Therefore, a balance between information from the observed data and contextualization is important for understanding and interpreting the results. Another limitation of dietary pattern analysis is that it requires a large amount of data and resources. Dietary intakes are difficult to assess, they change over time, and large samples are needed to have a good fit model in LCA (13). Nevertheless, using LCA in the first phase of public health program investigation can be very informative for the development of interventions for subpopulations in specific contexts.

Overall, *a posteriori* dietary pattern analysis is a promising way of investigating, interpreting and taking action to improve diet quality and health at the subpopulation level. Specific needs can be identified, interventions can be subsequently derived and the risk of overlooking some groups is reduced. It can guide and inform behaviour change strategies based on a holistic approach. However, it is worth mentioning that other methods have been recently explored in the field of nutrition, such as machine learning methods (18), for dietary patterns identification (19). Machine learning methods use automated data-driven strategies to find interaction among a wide range of variables (20). Therefore, considering the wide range of methods available, further study is needed to find the appropriate methods that best match the research question.

Simple dietary indicators can fill the data gap in public health

Simple dietary indicators are needed in nutrition and other fields for monitoring purposes (21). The fruit and vegetable component of the Global Dietary Recommendation score (FV-GDR) is a simple score to assess the diversity of FV consumption, correlated to actual intakes (Chapter 3) and it is a promising monitoring indicator (Chapter 4).

Although dietary risks are one of the top risk factors for the global burden of diseases (22) and malnutrition is still much more prevalent in the world (23), dietary data from many countries are still missing. Available and updated dietary surveys are lacking worldwide, which creates a relevant data gap. However, high-quality data from throughout the world are needed to inform programs and policymakers to improve access to healthy diets (24). Yet, actions have been taken by international organizations to support harmonisation in the collection of food consumption data and increase their availability and access (25).

Dietary consumption is difficult to assess, and require dietary assessment methods which are often burdensome and are resource intense in terms of time, costs and skills (21). This has created disparities in dietary research data generation between low-income and high-income counties. These disparities not only include the amount of data available but also the skills and resources to make use of the available data in terms of defining priorities of data needed, analysing data with appropriate tools, and interpreting the results to take actions and make decisions (24). The availability of simple and standardized methods to collect dietary data has been identified as a solution to this disparity, by increasing data generation and availability, making less represented populations more visible which are often the ones most in need, and equitizing nutrition research (26).

The FV-GDR is constructed from the DQQ, which is a standardized monitoring tool to collect information on dietary intake (27). The DQQ is based on the consumption of food groups (yes/no) and therefore it does not collect information on the amounts consumed, although correlates to it (Chapter 3). Concerning the FV component of the DQQ, the validation of this method allows comparison across populations and countries. Although the methodology of this tool is standardized, it is based on a list of country-specific sentinel foods that represent the FV most consumed and relevant in terms of amount across the whole country, so indicates consumption at national level. Therefore, it might not be the most optimal tool to use for subnational regions or specific population groups where, for instance, specific or indigenous foods are commonly consumed. Moreover, the selection of these sentinel foods could lead to an underestimation of the intakes (Chapter 3) when commonly consumed items in a specific area or season are not included. We found this for “other vegetables” and “other fruits” in our Vietnamese population because of the wide varieties available within the subgroups. Hence the development and validation of these sentinel lists are important when using it for subpopulations. In the validation study for the Chinese DQQ, the FV sentinel items captured 95-100% of the FV consumed (28,29), while in Ethiopia and Salomon Islands discrepancies in the sentinel foods were found in the FV questions (30). After our study, both the Nigerian and Vietnamese DQQs have been updated following a revision of the items included in the list.

The attempt to represent consumption at the country level highlights the value of this tool, and related FV-GDR, for monitoring consumption at population level. It allows comparison of FV diversity between countries but a global cut-off for adequacy is difficult to define. Although a higher FV-GDR correlates to higher quantities consumed (Chapter 3), a potential FV-GDR cut-off identifying sufficient intake differs per country and our data show these would be 0.5 for Vietnam and 1.5 for Nigeria. Hence a global cut-off would probably be misleading. Therefore, it is recommended to compare the FV-GDR in its continuous form between different settings, to evaluate the variety and diversity consumed rather than adherence to global recommendations.

Furthermore, the FV-GDR derived from the DQQ is a simple indicator which requires a limited amount of resources, compared to other dietary assessment methods, such as the 24-hour recall. It is recently made available for 124 countries, especially LMICs, and it is accessible to everyone (27). The data gathered do not require complex processing and are simple to analyse in terms of time and skills required, which suits frequent data collection for monitoring purposes at national and global levels, especially in low resources settings. Furthermore, the shortness, simplicity and high intuitively of the questionnaire decrease the burden on the respondents. This also facilitates the use of this score for the monitoring of large populations and precision of responses. These are all characteristics identified for the improvement of global monitoring of FV consumption (26) as the FV-GDR can be used for routine data collection of large populations, such as the Demographic and Health Surveys (DHS) (31). It is also a valuable indicator for the identification of gaps in diets and creates visibility of dietary needs. It can help in starting to set priorities in the health agenda of countries and advocating for increasing FV intake.

The FV-GDR provides the possibility to regularly monitor trends of and changes in FV consumption and how it fluctuates over time in low resource settings (32). This is also relevant for FV consumption in LMICs where consumption is highly affected by seasonality and fluctuates over time. Multiple data collection rounds to have all year-round descriptions of consumption can inform decisions and identify gaps in specific populations at a certain time of the year. Furthermore, it can be used to assess diversity and variety of FV availability and accessibility in projects that do not have diets as their main objectives. For instance, agriculture interventions that aim to improve food security via diversification of edible crops can make use of the FV-GDR to assess varieties; or other sectors of the food systems, such as production or supply. The provision of such an indicator to these fields would help in advancing nutrition to other fields and prioritize its intercorrelation with them (33). It is important to notice that the FV-GDR we used is limited to monitoring FV intakes and does not replace quantitative methods. The FV-GDR is based on a balance between feasibility, simplicity and accuracy.

It is easier to have an impact on large dietary gaps rather than change habits already engrained

FV are addressed as a single food group in the recommendation for healthy diets, as they are similar in low energy content, and richness in minerals, vitamins, and fibre. However, they are two different food groups. From epidemiological studies, health benefits have been reported for FV together, but also separately. Low FV intake each strongly contribute to cardiovascular disease mortality globally, with a larger effect of fruits compared to vegetables (34), especially in LMICs (35) probably because of the lower fruit intake. While in the period 1990-2019 diets low in fruits remained the fourth risk factor for the global burden of non-communicable diseases attributable to diets, diets low in vegetables dropped from seventh to ninth on the list of risk factors because of the rise of other risks such as high sodium consumption and low whole grains (36,37).

Generally, the investigation of barriers and drivers of consumption has been conducted for FV together (38–40). In LMICs, safety concerns are associated with reduced consumption of both FV (41), while higher educational levels and income are associated with an increased prevalence of meeting the recommended intakes (38,39). On the other hand, differences exist between several aspects of FV consumption. Affordability seems to be a barrier more for fruit than vegetables, as globally fruit prices are higher than prices of vegetables, especially in LMICs (42). FV are also eaten differently, on different occasions (43). Fruits are more often consumed raw as snacks or away from the main meals, contrary to vegetables which are often consumed cooked as part of the main meal.

Compared to the vegetable food group, the fruit food group is more affected by seasonality, which can be a determinant of availability and consumption. Especially in LMICs, seasonality affects and drives the availability, accessibility and affordability of fresh products during the year (44). For instance, some vegetables are available all year round, which supports daily consumption and limits the fluctuation of prices at the market level, as dark green leafy vegetables in our study settings (45,46). Differently in high-income countries, a wider range of products is available all year round regardless of seasonality. Consequently, in these settings desirability and motives may play a dominant role in food choices compared to contexts where food availability is limited. Moreover, home garden practices increased FV consumption and dietary diversity in LMICs (47). However, compared to fruits, vegetables are more accessible and common in home gardens because they are easier to grow with less space needed, also in urban areas (48,49).

In the food system, the food environment plays a dominant role in food choice and consumption. Within the food environment, defined as the interface between food acquisition and consumption within the food system, consumers are influenced by external and individual factors (50). External factors are availability, accessibility, and affordability, including also the types of markets and vendors where the food is purchased from and consumed (51). Moreover, individual factors such as knowledge, beliefs and habits play an important role in consumption. All these factors can differ for each food group purchased and consumed, as, for instance, household wealth status and affordability affect fruit consumption more than vegetable consumption, while convenience is a more important determinant of vegetable consumption (52). Therefore, investigating the determinants of FV together could reduce the ability to find specific drivers of consumption of the individual food groups. Identification of these differences can be relevant for the development of tailored interventions that aim to improve consumption of both food groups.

In our study population, the limited number of individuals consuming fruits was identified as a larger dietary gap compared to vegetables (42). Subsequently, the FVN interventions were tailored to fruit intake, which aligns with a higher fruit intake of the respondents exposed to the interventions compared to the control areas (Chapter 5). This suggests that the relevant barriers to fruit consumption were well-identified and addressed. However, these barriers are context-specific and cannot be generalized to other populations without prior investigation of their determinants.

As found in our study, the differences between FV consumption may need different strategies to increase FV consumption. In our context, it seemed easier to change fruit intake rather than vegetable intake, through adding on a new behaviour or addressing a larger problem rather than changing existing behaviour. One reason could be that it is easier to recognize and experience a gap such as low fruit consumption. Social protection interventions, such as receiving cash or incentives to buy food, are promising in changing behaviours because they provide direct and tangible means that can be immediately used (53,54). These help in maintaining the compliance of people because they see a direct result and benefit of having more food. On the other hand, behaviour change communication strategies such as education or advertisement are based on the responsibility of respondents and require a higher level of willpower and effort from the respondent to change behaviour. Behaviour change communication strategies are effective in changing eating behaviours (55) but the intensity of the interventions and the elements that need to be included are still unclear (56).

Furthermore, there is a difference between changing existing behaviour and promoting new behaviours. It is more challenging to change a behaviour that is sustained and engrained over time and often less conscious (57). In the case of FV, vegetables are consumed almost daily, in traditional recipes although in small amounts, whereas fruits are consumed less often, as we also observed in our Vietnamese and Nigerian populations (Chapter 2-5). Fruits can be added to traditional diets without changing other habits, whereas modifying recipes might be required to increase vegetable consumption. Changing traditions can be difficult because it would affect also acceptability and taste. An entry point for reformulating recipes and increasing the amount of vegetables in already prepared dishes could be out-of-home consumption, as it an increasing practice in urban areas (58). A study in Nigeria showed that consumption of dark green leafy vegetables increased after cooking lessons to women on including greens in the stew (59). On the other hand, the dark green leafy vegetables were a completely new ingredient of the recipe, which could be perceived as a new behaviour. The opportunity to change consumption of a food group depends on how deeply a behaviour is engrained in people's lives. Perceived control of behaviour or intention is a relevant driver of behaviour (59).

On the other hand, dietary patterns change over time, often documented as the nutrition transition, partly driven by external changes in the food environment and food availability. Changing existing behaviour and promoting positive behaviour, could be achieved through the food environment. Specific intervention strategies have been suggested to induce healthy habits and increase habit strengths, such as making changes in the food environment (43). A systematic review highlighted the effectiveness of nudging in increasing FV choice but the evidence is still limited (60) especially for LMICs. Intervening in the food environment could promote positive behaviours, also making them sustainable in the long term.

Evaluation of complex interventions implemented in 2019-2021 faced study design adaptation and limitations

The appropriate design to assess causality and attribute the findings to a project would have been conducting a randomized controlled trial. However, the co-creation of the FVN interventions with respondents (consumers and vendors) did not allow such a design, as randomisation on an individual basis was not possible. Randomisation on cluster level (i.e. area) would have been an option, but only a few clusters (areas) could be included. Therefore, for the evaluation of the FVN project a longitudinal (quasi-experimental) study was initially planned with a baseline-end-line comparison of FV intake together with a monitoring study to track changes in FV consumption during the implementation of the FVN interventions.

However, after the baseline assessment in 2019, the project had to stop due to the restrictions imposed to limit the spread of COVID-19 in both Vietnam and Nigeria. When it was possible to start again (mid-2020), a large proportion of the respondents (62% in Vietnam and 39% in Nigeria) had moved out of the project areas, or were not reachable anymore, reducing the sample size and resulting in a selection bias. This made the baseline-end-line comparison less meaningful, and we changed the study and project design, adding new respondents from the same areas, in the project, and changing the evaluation of the project to a cross-sectional study comparing FV intake at end-line of subjects from the intervention areas with subjects from control areas.

Although the new respondents were selected using the same criteria, some selection bias cannot be excluded. In Vietnam, the new respondents included slightly more women and were younger compared to the original population while the new Nigerian respondents were slightly higher educated. Furthermore, the absence of baseline dietary intakes of the study population prevented us to adjust for them in the comparison between individuals from the intervention areas and control areas. We could not rule out that possible differences could have been present already at baseline, affecting the interpretation and especially generalizability of the findings in Chapter 5 showing an increase in consumption (Box 5.1).

Furthermore, data collection also had to be adapted since it was impossible to collect data in person through home visits. For the monitoring study, data collection was conducted by phone interviews rather than household visits as originally planned. This could have also caused selection bias. It was possible to reach only respondents with a phone, who were able to use it and were available during the day, which could be an indicator of higher socioeconomic status and educational level. However, the total dropout during the study was limited (18% in Vietnam and 22% in Nigeria) and the sociodemographic characteristics did not differ between the respondents who stayed in the project and who dropped out (Chapter 4). During the COVID-19 pandemic, it was common to collect data either with self-administrated questionnaires or phone interviews (61). Although the self-administrated method requires a certain level of education of respondents (62), phone interviews are more challenging for enumerators to create a rapport with the respondents (63). Since the original study was not planned to collect data via phone interviews, our enumerators were not trained to conduct them which could have introduced information bias. However, the DQQ used for the monitoring study seems to be a suitable method for phone interviews since calls are recommended for short questionnaires, frequent surveys and surveys to understand trends and changes (64). Furthermore, respondents had more privacy to answer the questions (65).

Hence, on the one hand, the logistic and physical limitations introduced by the COVID-19 pandemic were not possible to predict and we overcame them to the best of our possibilities and knowledge. On the other hand, regardless of these limitations introduced by the timing of the project, it remains difficult to evaluate complex nutrition-sensitive projects. The factors that affect consumption are multiple and are difficult to control. Assessing intakes at baseline and end-line, and monitoring them, is informative in terms of actual intakes and the overall quality of the diet of the study population. This already provides information on the overall project. However, establishing causal effects and integrated project evaluation remains difficult.

Nutrition-sensitive project impact evaluation requires a broader perspective for scaling up

Given the complexity of nutrition-sensitive projects, the multiple factors involved, and the methodological challenges (66) (addressed and others), the use of mixed methods could help in generating a wide range of learnings and outcomes. Qualitative and quantitative methods could be complementary in improving the robustness of the impact evaluation (67).

Qualitative methods provide insights and details on the problem and the underlying reasons. For instance, in-depth interviews with respondents of the interventions can help in the identification of motives, beliefs, barriers or expectations around FV consumption. This was indeed found relevant in the FVN project for the identification of the main barriers to FV consumption and the development and adaptation of the interventions (1,3,4). Furthermore, qualitative methods are useful to investigate how the interventions are perceived by the target population, especially if these are related to education and knowledge dissemination. They can be used during the whole process of a project, before and during the implementation of interventions but also after to explain the found effect.

Quantitative methods capture to which extent the problem exists and allow to find associations. The comparison of FV intake between subjects from an intervention and a control area provided a quantitative and tangible outcome of the project. However, the study design did not allow us to attribute our final results to the interventions solely. There is an ample range of factors affecting FV consumption, which we could partly adjust for, but it is a behaviour that takes time to change for which it is difficult to estimate the long-term impact.

Other methods were explored to investigate the causal pathways used in the evaluation of multi-sectorial interventions to increase FV intakes. Our study design aligns with the results of a review of the effectiveness of interventions aiming to increase FV consumption which reported differences between groups at follow-up as one of the main study designs for evaluation, together with a difference between the change in intakes in exposed and control groups, and change in intakes within groups (68). Furthermore, other studies, evaluated multi-sectorial interventions using regression analysis (59,69), and structural equation modelling (70). This could help by taking the multiple factors affecting dietary intake into account. In general, more research is needed to investigate the methods to evaluate the impact of complex projects on dietary intakes.

In general, the selection of outcome indicators needs to be aligned with the research questions. We used two 24-hour recalls per participant to estimate FV intakes. Considering the amount of resources needed and the burden on the respondents, it was a good method to estimate intakes at the population level. We used the DQQ for the monitoring of intakes over the period of the interventions, and this fulfilled the purpose of estimating the trend of consumption and regularly collecting data limiting the fatigue of respondents. But it might have been limited to capturing only one dimension of consumption. Subsequently, other effects of the interventions were not monitored on the quantities consumed or diversification within the same specific FV group.

We presented two specific case studies and we need to consider that our studies and project were implemented in a specific population. We targeted adults, mainly women, living in urban and peri-urban areas. This limits the generalization of our findings to the general Vietnamese and Nigerian population. However, the use of comparable processes in two different contexts provided learnings on the methods used that can be applied in other contexts as well. The identification of major dietary barriers and drivers, the characterization of the target consumers, and the co-creation of the interventions are all important elements of nutrition-sensitive projects that can be used in other populations and countries.

The evaluation of interventions should aim to address questions about the value and relevance of the project based on its theory of change. A broader perspective and evaluation of more indirect outcomes, such as those related to the implementation, would help in scaling up interventions. The inclusion of research questions that go beyond the aim of the interventions fall into the category of implementation science (71). It includes outcomes on the process and monitoring of the interventions such as feasibility, coverage, acceptability, and quality and these are needed to ensure improvements and scaling up.

The importance of consuming fruit and vegetable intake has been already established (35) and now there is need to understand the broader picture of how to increase consumption at the population level in the long term. The implementation of this requires an extra level of investigation. The evaluation of projects should generate information for further implementation. Additional questions and stakeholders would be valuable to include in the project to assess how the project can be implemented in the existing system, how the learnings from the project evaluation can be used to improve the quality of the current system, how can it be scale-up at a country level, and how it can be sustained at the community level (71).

However, the question remains whether it is feasible to have the two aspects, evaluation and implementation, in the same project. It is important to generate outcomes useful for the implementation to improve and scale-up the project, but this also requires a larger amount of resources.

Implications for public health

Our research identified that low FV consumption needs to be addressed with integrated interventions at the food system level. These interventions are connected, implemented simultaneously, and address different aspects of FV consumption. This allows for a comprehensive approach to tackle the issue since there are multiple causes of low FV consumption. Integrated interventions also target several stakeholders involved in the supply and consumption of FV, including consumers and vendors who play an important role in the drivers of consumption such as availability, affordability, and accessibility. Additionally, using a participatory approach with co-creation of interventions with the target population supports deeper investigation of context-specific causes and tailoring of interventions.

We also identified the importance of going beyond targeting population groups based solely on geographic area (urban-rural), income, or sociodemographic characteristics (sex, age). Identifying different dietary patterns and characterizing the consumers of each specific pattern is important for determining nutritional needs. This information is useful for prioritizing the specific focuses of projects and developing and tailoring interventions.

Lastly, the FV-GDR is a simple method that can help close the data gap on FV consumption, especially in low-resource settings. It can be used to regularly monitor FV consumption at national and local levels, for routine surveys of large populations and for monitoring projects and interventions. Additionally, the simplicity of FV-GDR expands the possibility of including a nutrition indicator in other fields that do not have nutrition as their main goal. The availability of FV consumption data can be the first step in advocating for addressing important nutritional risks and promoting healthy diets.

Implications for future research

Our studies identified implications for future research on evaluating nutrition-sensitive integrated projects. Including implementation science in the evaluation of such projects would provide a better understanding of their effects. The quality of interventions and their implementation process is crucial for the overall impact and can expand our understanding of outcomes. Furthermore, using a combination of qualitative and quantitative methods can complement each other in creating evidence for project evaluation and developing a more robust and comprehensive evaluation strategy.

Future studies should investigate the best analyses for determining the causal pathway of integrated nutrition-sensitive interventions and dietary patterns. More robust study designs and statistical analyses, such as controlling for baseline information and the other factors that affect FV consumption, should be explored to attribute findings to implemented interventions and projects. For instance, structural equation models could be an option to link interventions implemented, determinants of consumption addressed, and final outcomes observed. Additionally, further research is needed to explore different methods for defining dietary patterns and identify the analysis that best matches the research questions.

Lastly, future studies should explore the inclusion of the quantitative aspect of FV consumption in the FV-GDR. Given the impossibility of estimating exact amounts due to the simplicity of the score, but the crucial role of FV for healthy diets, investigating a cut-off point for adequacy or including categories of consumption in the score is worthwhile. Further research is needed to address differences across countries and populations in terms of meaningful increases in FV consumption when including categories of amounts. Large population and multi-country studies could provide the opportunity to explore the inclusion of quantities in the FV-GDR.

Conclusions

This thesis shows that an integrated nutrition-sensitive project within the food system had a positive effect on increasing the FV intake of the target populations. This thesis generated knowledge on the adaptability of the studies and projects, comparable processes and methods that can be applied in other contexts and offer possibilities for the evaluation of integrated nutrition-sensitive interventions at the food system level. We showed that different dietary patterns coexist among low-income populations in urban Hanoi and Ibadan. Differences in diets and characteristics of consumers provide the possibility to develop tailored strategies to improve the quality of the diet. We identified the FV-GDR as a valid indicator to monitor FV consumption at the population level. This indicator can be used in nutrition surveys to routinely monitor FV intakes, especially in low-resource settings, and provide a tool that other sectors can use to include nutrition. The overall evaluation of the FVN project showed higher intakes of mainly fruits in the intervention areas, suggesting a positive impact of the FVN project and supporting the relevance of multi-sectorial nutrition-sensitive projects. Future evaluation of integrated nutrition-sensitive research projects should include strategies to assess the implementation and causality pathways of the interventions on FV consumption. Furthermore, the possibilities to include information on the FV quantity consumed in the FV-GDR need to be explored.

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Summary

Fruits and vegetables (FV) are important components of healthy diets. However, global consumption is low, especially in low- and middle-income counties. Several are the determinants of FV consumption that can be addressed to increase consumption. Nutrition-sensitive interventions that target the consumer and supply side of the food system have the potential to promote FV consumption in low-income populations. Using the examples of Vietnam and Nigeria, with a focus on urban contexts, we aimed to evaluate the integrated nutrition-sensitive FVN project that aimed to increase FV consumption of low-income adults in urban and peri-urban Hanoi and Ibadan and to develop an indicator to monitor FV intake.

This thesis aims to characterize the dietary patterns of consumers living in urban and peri-urban Hanoi, Vietnam and Ibadan, Nigeria, and to evaluate the FVN project through the monitoring of FV intakes during the implementation of the interventions and a final evaluation of FV intakes. Additionally, it aims to validate a simple score to assess FV consumption at the population level.

Chapter 2 identifies the dietary patterns of low-income adults in Vietnam and Nigeria and characterizes consumers and the diet quality of these dietary patterns. We used Latent Class Analysis to characterize dietary patterns of 397 Vietnamese and 363 Nigerian low-income adults, 18-49 years old living in urban and peri-urban areas in Hanoi and Ibadan. Food intake was assessed with duplicate quantitative 24-hour recalls (24hR) and diet quality was assessed in terms of diversity (Food Group Diversity Score), risk of non-communicable diseases (Global Diet Quality Score) and micronutrient adequacy (Mean Probability of Adequacy). The bias-adjusted three-step approach was used to investigate the associations of sociodemographic characteristics and diet quality with dietary patterns. In Vietnam, we identified three dietary patterns: “Animal based” (38% of the population), “Rice, legumes and vegetables” (31%) and “Rice, noodles and pork” (31%). Consumers differed in age, area, household size, marital and living standard indicator, education, occupation and diet quality. Consumers of the “Rice, noodles and pork” dietary pattern had the lowest diet quality. In Nigeria, we identified three dietary patterns: “High intakes and vegetables” (39%), “Low intakes” (36%), and “Dairy and sugar” (25%). Consumers did not differ in sociodemographic variables. Consumers of the “Low intakes” pattern had the least diverse and adequate diet. Different consumer groups with different food choices, resulting in unique dietary patterns, coexist in the same population. Understanding these consumer groups and the drivers of their food choice will help to tailored interventions to diversify diets and to prevent unhealthy consumption patterns.

Chapter 3 address the need of a simple-to-administer and low-priced indicator to monitoring fruit and vegetable intake at the population level, especially in low-resource settings. We investigated the relative validity of the fruit and vegetable component of the Global Dietary Recommendations score (FV-GDR) collected with the Dietary Quality Questionnaire (DQQ) to measure FV intake by comparison with a 24hR as a reference. We used data collected from 620 Vietnamese and 630 Nigerian adults in 2021. We found proportional differences in the prevalence of intake of 'vitamin A-rich vegetables', 'other vegetables', and 'other fruits' in Vietnam, and all vegetable food groups in Nigeria. In both countries, we found a small difference in the total FV-GDR from DQQ compared to the 24hR, and the percentage of agreement between the two methods was quite high for the majority of the food groups. The FV-GDR calculated from the DQQ correlated with the actual intake, although less strongly than the FV-GDR from 24hR. The DQQ is a promising low-burden, low cost and simple tool to calculate FV-GDR and to monitor total FV consumption at the population level. This provides the possibility of regularly evaluating an important aspect of diet quality in low-resource settings.

Chapter 4 monitors and evaluates the trend in FV intake before, during and after implementation of a set of nutrition-sensitive food system interventions over a 1-year period in Vietnamese and Nigerian urban and peri-urban females. We used the DQQ to assess FV food groups consumption among 600 Vietnamese (Hanoi) and 610 Nigerian (Ibadan) females, before, during and after the interventions. The FV-GDR was calculated and compared between exposure groups with (mixed) count modelling. The trend in consumption of individual FV groups was analysed with mixed logistic regression. The FV-GDR was stable over time and a small increase was observed after the intervention period especially in Nigeria and in urban Vietnam. A decrease in the total score was observed in peri-urban Vietnam. Fluctuations were detected in the probability of consumption of individual FV groups over time especially within the fruit groups, probably due to seasonal availability of the products. The degree of exposure could not explain differences in FV intakes. We found a marginal increase in the proportion of females consuming FV during the FVN interventions in both countries. The FV-GDR appeared to be a simple, quick and easy-to-use indicator for monitoring diversity, variety and consumption.

Chapter 5 evaluates the effect of an integrated nutrition-sensitive project (FVN project) that aimed to increase FV consumption in low-income urban adults in Hanoi, Vietnam, and Ibadan, Nigeria, through the simultaneous implementation of three interventions at the market and consumer levels. FV intake data were collected after eight months of exposure to the project with repeated quantitative 24hRs and compared between an exposed (Vietnam n=283; Nigeria n=291) and a control group (Vietnam n=299; Nigeria n=335), considering potential confounders: age, sex, neighbourhood, BMI, household size, education and occupation. The adjusted intake of total FV (169 g/d, 95%CI 132, 205), fruits (156 g/d, 95%CI 122, 193) and vegetables (12 g/d, 95%CI -2, 26) was higher in the exposed Nigerian population compared to the control group. In Vietnam, only the intake of fruit (24 g/d, 95%CI 12, 34) was higher in the respondents of the intervention areas. Participants exposed to all three interventions reported slightly higher intakes compared to those who were exposed to fewer interventions, but these differences were not statistically significant. Our results suggest that integrated approaches of nutrition-sensitive food system interventions may offer the potential to increase fruit and probably also vegetable consumption. Co-creation of interventions provides the possibility to address the differences across contexts.

Chapter 6 summarizes the main findings and reflects on their implications. Based on our findings, the FVN project is likely to have a positive effect on FV intake of the study populations, larger on fruits and in the Nigerian context. The use of an integrated approach and cocreation methods of the FVN project could be generalized in other contexts and the FV-GDR has the potential for monitoring FV intake at national and global levels. This thesis contributed to generating knowledge on the effectiveness and the evaluation of integrated nutrition-sensitive projects at the food system level. Future steps include the investigation of more robust methods to attribute the effects observed to the interventions.

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About the author

Giulia Pastori is a public health nutritionist who specializes in food and nutrition security, nutrition programs and food systems.

Giulia was born in Milano, Italy. She studied Dietetics at the Universta' degli Studi di Milano, specializing in clinical nutrition. After her Bachelor, in 2016, she moved to the Netherlands to follow a master's program in Nutrition and Health, with a specialization in Epidemiology and Public Health, at Wageningen University and Research. As part of the master's program, she investigated the determinants of stunting in Malawian children, and worked at the Wageningen Center for Development and Innovation, where she supported the evaluation of a nutrition-sensitive project aimed to improve nutritional status of women and children, implemented in Uganda and Zambia.

After her master, she started working as a junior researcher at the Division of Human Nutrition at Wageningen University. She supported data collection and data analysis for the evaluation of nutrient adequacy of consumers in Bangladesh, Ethiopia, Nigeria and Vietnam, the "Diet Quality" project and the "Fruit and Vegetable intake in Vietnam and Nigeria" project. In 2020, she started her PhD program within the "Fruit and Vegetable Intake in Vietnam and Nigeria" project. Her research focused on the monitoring and evaluation of a nutrition-sensitive program to increase fruit and vegetable intake in low-income populations living in urban areas. During her PhD training, she assisted MSc courses, supervised MSc thesis students, and presented her work at several international conferences.

Overview of completed training activities

Discipline-specific activities	Organizing institute	Year
Agriculture for Nutrition and Health (4NH) yearly meeting	WUR	2020
Micronutrient Forum	MN Forum	2020
eICDAM	ICDAM	2021
ANH Academy	ANH	2021
ANH Academy	ANH	2022
Final project (FVN) meeting	NIN	2022
IUNS	IUNS	2022

General courses	Organizing institute	Year
Supervising BSC and MSc thesis students	VLAG	2020
Introduction to R	VLAG	2020
SPADE	RIVM	2021
Efficient Writing Strategies	WGS	2020
Bridging across cultures	VLAG	2021
Latent Class Analysis course	Statistical Innovations	2021
Exposure Assessment in Nutrition Research	VLAG	2022
Scientific Writing	VLAG	2022
Career Orientation	VLAG	2023

Other activities	Organizing institute	Year
Preparation of research proposal	Human Nutrition and Health	2020
PhD study tour	Human Nutrition and Health	2022
Department meetings and seminars	Human Nutrition and Health	2020-2023
Paper Cafe'	Human Nutrition and Health	2020-2023
PhD Committee	Human Nutrition and Health	2020-2023

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