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# Impact of Participative Nutrition Interventions on Iron-Rich Food Consumption in Urban Senegalese Adolescent Girls

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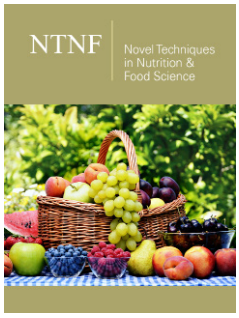


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## Abstract

**Background:** Adolescence is a window of opportunity to rectify nutritional deficiencies. Nonetheless, to improve dietary behaviors and nutritional status of adolescents, it is essential to design sustainable and effective nutrition interventions.

**Objective:** To design, implement and evaluate impact of interventions based on the intervention mapping/IM model, on iron rich food/IRF consumption among Senegalese adolescent girls.

**Methods:** Experimental design targeting girls aged 13-18 from two colleges in the city of Dakar with one college receiving interventions (EC) and the other serving as a control (CC). Interventions included one nutrition education session, four cooking and recipe sharing sessions and a six-week subsidy to a local vendor for offering affordable IRF. Daily consumption of IRF among adolescents in both colleges, as well as individual and environmental factors that might influence it, were measured before and after interventions.

**Results:** After interventions, the proportion of girls in EC who no longer perceived that consuming IRF caused weight gain increased by about 25% ($p=0.001$), as did the proportion who felt able to consume at least 85g of IRF/day even if they were not able to prepare IRF themselves ($p=0.040$). As compared to before interventions (65%), a lower proportion of girls in EC perceived the price of IRF as a barrier to their daily consumption after interventions (24%, $p<0.001$). In EC, after interventions, the average daily consumption of IRF increased by approximately 25g ($p<0.001$) while no change was observed in CC ($p=0.559$).

**Conclusion:** Interventions based on IM targeting individual and environmental factors could be relevant for improving IRF consumption of Senegalese adolescent girls.

**Keywords:** Iron-rich foods; Intervention mapping; Theory of planned behavior; Adolescent girls; Individual and environmental factors; Senegal

## Introduction

Adolescence is a rapid phase of growth and development during which nutritional requirements are high. Girls at this age are particularly vulnerable to iron deficiency that leads to anemia which has consequences on cognitive ability, physical endurance and immunity [1-3]. Yet, this period is an opportunity to rectify nutritional deficiencies and establish good dietary behaviors [4].

In Senegal, about 2 out of 3 adolescent girls are anaemic, a situation that has been stagnant in the past decade [5,6]. Current strategies implemented in the country to reduce and control iron deficiency and iron deficiency anaemia are large-scale Iron/Folic Acid (IFA) fortification of wheat flour and IFA supplementation for pregnant women. Furthermore, although interest in dietary diversification and/or modification strategies is growing, nutritional interventions for adolescent girls focused on increasing dietary iron intake and bioavailability are scarce.

Dietary diversification and/or modification strategies aim to improve the availability, access and use of foods elevated in bioavailable micronutrients [7]. They may include increasing the production and consumption of foods high in bioavailable iron, such as meat, poultry and fish; reducing the consumption of foods rich in phytates and tannins to improve iron absorption; increasing the consumption of foods known to enhance iron absorption; and optimizing the processing, preservation and marketing of iron-rich foods [8,9]. In numerous studies, diet diversification and/or modification strategies, including those focused on increasing consumption of iron-rich foods/IRF, have been associated with continued improvements in iron status in women of reproductive age and children in low-and middle-income countries [10-13].

According to Hargreaves et al. [14], among adolescents, interventions should resonate with their values and social context to be successful. Thus, understanding and harnessing factors driving adolescent food choices and environments could be central to designing effective nutrition programs for this age group. In this regard, it is important to use planning models which lay out guidelines to lead the program design process. Such models provide a structured framework for developing, implementing and evaluating behavior change interventions [15,16].

Bartholomew et al. [17] proposed the intervention mapping/IM, a planning framework that applies an ecological approach to understanding health problems and intervening at multiple levels (individual, interpersonal, organizational and community), in partnership with all stakeholders. IM provides a detailed protocol that begins with the recognition of a need or problem, followed by the identification of a solution and the evaluation of its implementation [18]. Several nutrition interventions have successfully used IM to promote better nutrition behaviors and healthy eating among adolescents [19-22].

Using IM to guide our research process, we first conducted an analysis of needs and of their main determinants among urban Senegalese adolescent girls to document their consumption of IRF [23]. Results have shown that 83% of them had a daily intake below the recommendation of 84g of animal protein foods from the EAT-Lancet Commission on healthy diets from sustainable food systems [24], which is worrisome. Subsequently, factors underlying this low consumption of IRF were explored using an extended version of the theory of planned behavior/TPB (unpublished data). Results revealed that overall, adolescent girls did intend to consume at least 85g of IRF every day. However, some behavioral and control beliefs, such as thinking that IRF can make you gain weight, as well as environmental barriers such as the high price of IRF appeared to limit the adoption of the behavior (unpublished data). This paper reports the results of the next steps of the IM process which were to define, to implement and to assess the impact of an intervention on the consumption of IRF among urban Senegalese adolescent girls.

## Methods

### Study design and sample

This is an interventional survey targeting adolescent girls aged 13-18 years from two colleges purposively selected in the city of Dakar, Senegal. One college was randomly selected to be the experimental setting where interventions would be defined and implemented, while the other college served as a control.

In the following sections, methods are presented according to the six stages of the IM process [18]: (1) needs assessment, (2) definition of program objectives, (3) selection of intervention methods, (4) operationalization of intervention methods and practical applications, (5) program implementation planning and (6) program evaluation.

### Step 1: Needs assessment

The first stage of IM focuses on a broad and in-depth understanding of the health problem and its determinants, namely the associated behaviors, their main determinants and the target population. As indicated above, this step was carried out in our first part of the research.

### Step 2: Definition of program objectives

Step 2 of IM involves identifying objectives for change related to behavioral determinants identified in the needs assessment. With the adolescents, these objectives were defined with respect to the factors limiting IRF consumption that had already been documented. To do this, three Focus Group Discussions (FGD) of approximately 60 minutes were held in French with the girls (15 per group) from the experimental college.

During FGD, results of the analysis of factors underlying the low IRF consumption were presented. Some items related to behavioral and control beliefs as well as environmental barriers that seemed to further limit IRF consumption were listed and presented to the girls. For each item, they were asked to propose an objective for change and an intervention that would help to achieve this objective.

Next, responses were compiled, those expressing the same idea were grouped together and the frequency of mentions of each was calculated. Suggestions of objectives for change and interventions that were mentioned by at least 50% of the girls were retained and used in the development of objectives and content of interventions. Based on girls' responses and taking into account evidence from the literature as well as time and budget, the following four objectives for change were formulated:

a. Improve adolescent girls' knowledge of the importance of consuming IRF to preserve their health and that of their future children.

b. Demystify certain beliefs about IRF, particularly those related to weight gain due to their consumption.

c. Help adolescent girls gain confidence in their skills to cook IRF.

d. Improve the physical and financial accessibility of IRF.

### Step 3: Selection of intervention methods

To select Behavior Change Techniques (BCTs), we referred to Michie and colleagues' [25] taxonomy while also taking into account activities proposed by girls during FGD, their feasibility,

relevance and acceptability. Table 1 shows the selected BCTs, their descriptions, and the target determinants.

**Table 1:** Behavior Change Techniques (BCT) according to target determinants.

| Target Determinants | Selected BCT | Description of BCT |
|---|---|---|
| Behavioral belief | Provision of general information on benefits of Iron-Rich Foods (IRF) consumption and of consequences of not consuming IRF | Provide information (e.g., written, verbal, or visual) about the importance of consuming IRF to preserve their health and that of future generations and health consequences of not consuming IRF |
| Perceived Behavioral Control (PBC) | Incentivizing practice | Encourage adolescent girls to develop the skills needed to consume IRF on a daily basis |
| Environmental Barriers (EB) | Restructuring of the environment | Help adolescent girls to alter their environment to be conducive to the daily consumption of IRF |

### Step 4: Operationalization of intervention methods and practical applications

At this stage, BCTs developed in step 3 were operationalized. Specifically, the sequence and content of interventions were identified. First, nutritional education sessions were designed to put into practice the first selected BCT (provision of general information about the consequences of not consuming IRF). To do this, girls of the experimental college were divided into four groups (n=17 per group) and a nutrition education session was conducted with each group. During each nutrition education session, the first author made an oral and written presentation (on the blackboard) to convey key messages on the following points:

a. Importance of consuming IRF to improve one's health and that of the future generation.

b. Consequences of iron deficiency and iron deficiency anemia.

c. Identification of energy-rich and micronutrient-poor foods that, unlike IRF, can lead to weight gain.

Also, each nutrition education session included two interactive games and one persuasive communication. During interactive games, girls were given multiple choice questions related to key messages delivered in the theoretical presentation and they were asked to choose the correct answer from the blackboard. Then, the persuasive communication activity consisted of selecting at least two girls to deliver a speech of approximately two minutes aiming to raise awareness of their peers on one of the key messages. Each nutrition education session lasted approximately 60 minutes and took place in school's classrooms.

Thereafter, for the operationalization of the second BCT (Incentivizing Practice) model-based learning was chosen as the activity [26]. To do this, four cooking and recipe sharing sessions were conducted. First, a cooking activity was done with a local chef who prepared and presented five recipes using five different IRF (meat, poultry, fish, eggs, shellfish). All recipes prepared by the chef were shared with the girls so they could try them. Thereafter, three hands-on recipes and meal sharing sessions were conducted. During each session, five randomly selected girls from among those who attended the cooking session with the chef each chose and prepared one of the five recipes provided by the chef. Each girl presented her dish to her peers and explained how she prepared it. Other girls could also make suggestions. All these activities took place over a four-week period and were conducted in the school. Finally, for the last BCT (Restructuring of the environment), we chose to improve the physical and financial accessibility to IRF. The objective was to allow adolescent girls to have access to iron-rich meals, meaning that a sandwich with at least 45g of liver, eggs, meat, or tuna at an affordable price of 300 CFA francs (0.50$ US) or less would be available in at least one point of sale where adolescent girls buy meals while at school. To do so, an exchange and sensitization meeting was conducted with one of the meal vendors near the school (chosen by the girls). The meeting lasted about 60 minutes and was attended by the first author and ten (10) girls. The vendor was sensitized on the importance of consuming IRF. During this meeting, the girls suggested prices for IRF ranging from 100 to 300 CFA francs according to the type of meals. The budget needed to support the seller in offering IRF at affordable prices was also discussed.

### Step 5: Implementation planning

Interventions were implemented between May and June 2019 by the first author. Partners (college management staff) and targets (adolescents) of the program were also directly involved throughout the process so there were no obstacles to the implementation. The number of activities completed was counted and recorded along with the number of girls who participated in each activity.

### Step 6: Program evaluation

The last step in IM is the evaluation of the impact of interventions on the targeted problem. This evaluation phase was conducted during the last week of June and the first two weeks of July 2019. First, the impact of interventions on adolescent girls' consumption of IRF was measured using a Food Frequency Questionnaire (FFQ) developed during the first part of the study [23]. Target foods in the FFQ were IRF from animal sources, namely red meat (beef, mutton, lamb), poultry, fish, shellfish, organ meats and eggs, according to the list currently used in national surveys [27].

Thus, the consumption of IRF among adolescent girls in the experimental and control colleges was measured after interventions and compared to that measured before interventions, in February 2019. The FFQ was administered by sixteen interviewers who were recruited and trained in the methodology and data collection tools [23].

In addition, individual and environmental factors that may influence daily IRF consumption were documented before and after interventions in both colleges. Hence, the same questionnaire developed in the first part of the study (unpublished data) was used to collect information on each component of the theoretical framework, namely psychosocial factors (attitude, subjective norm,

perceived behavioral control and their respective set of beliefs), some environmental factors, and the intention to consume 85g of IRF per day, which is the studied behavior. The questionnaire, composed of thirty-nine (39) items, was a self-administered tool that was completed by each adolescent girl in her classroom during a school day.

## Data Analysis

Responses on a five-degree scale for each statement of the questionnaire on individual and environmental factors associated with the daily IRF consumption were combined as follows: negative responses (e.g., strongly disagree/rather disagree) were grouped together as well as positive responses (e.g., strongly agree/rather agree) while neutral responses were considered as a category on their own. Thereafter, for each item of the questionnaire, the distribution (%) of girls in each of the three categories was determined before and after interventions for each college. Fisher's exact tests were performed to compare frequency distributions first before/after interventions for each college.

In the experimental and control colleges, the total amount of each IRF consumed over the seven days before and after interventions was calculated in grams and then reported on a daily basis [23]. The daily intake (also in grams) of all IRF combined (red meat/poultry/fish/shellfish/organ meat and eggs) was also determined. Paired-sample t-tests were performed to compare average daily amounts of total IRF consumed before and after interventions in each college. In addition, Pearson chi-square tests were performed to compare proportions (%) of girls with average daily consumption (g/day) of all IRF combined ≥84g before and after interventions in each college. Data were analyzed with the SPSS software (Statistical Package for Social Sciences/SPSS, Version 21.0, Armonk, NY: IBM Corporation). A p value <0.05 was used as the criterion for statistical significance.

## Ethics

The study was approved by the ethical committee of the National Health Research of Senegal (#000106/MSAS/DPRS/CNERS) and by the Research Ethics Committee of Laval University (#2018-214/17-12-2018). Authorizations were also obtained from the Ministry of the National Education/School Medical Control Division, Dakar/Senegal. Written informed consent was obtained from the parent/tutor of each adolescent and each girl also provided her written assent to participate.

## Results

Overall, in the experimental college, 97% of girls (n=66) received a nutrition education session. In terms of learning by modeling, 94% of them (n=64) attended the cooking session conducted with the chef. However, all girls (n=68) received the recipe cards provided by the chef. For the three hands-on recipes sharing and meal preparation sessions, the participation rate was 96% (n=65). During the meeting with the vendor, it was agreed to provide her with financial support of 20,000 CFA francs (32$ US) so that she could sell IRF at affordable prices to girls.

### Behavioral beliefs

Just over half of the girls in the experimental college responded negatively to the item "For me, consuming at least 85g of IRF would make me gain weight" after versus one-third, before interventions (Table 2). The difference in proportions before and after interventions was significant in this college, while no difference was observed in the control college (Table 2).

**Table 2:** Distribution (%) of girls in the experimental (n=68) and control (n=68) colleges on a three-category scale of the behavioral belief item: "For me, consuming at least 85g of Iron-Rich Foods (IRF) would make me gain weight", before and after interventions.

| Experimental College | | | | |
|---|---|---|---|---|
| Items | % by category | | | P-value* |
| For me, consuming at least 85g of IRF would make me gain weight | Slightly/Very | Neither likely nor unlikely | Slightly/Very | |
| Before interventions | 27 | 30 | 42 | |
| After interventions | 53 | 20 | 27 | |
| | | | | 0.001 |
| **Control College** | | | | |
| Items | % by category | | | P-value* |
| For me, consuming at least 85g of IRF would make me gain weight | Slightly/Very | Neither likely nor unlikely | Slightly/Very | |
| Before interventions | 26 | 32 | 41 | |
| After interventions | 21 | 25 | 54 | |
| | | | | 0.448 |

### Control beliefs

After interventions, more than half of girls in the experimental group felt able to consume at least 85g of IRF even though they were not able to prepare IRF themselves, as compared with one-third before interventions (Table 3). Also, about two out of three girls felt able to consume at least 85g of IRF even though they thought it might make them fat as compared to one out of three before interventions (Table 3). These differences in proportions before and after interventions were significant. In the control college, there was no significant difference between the pre-and post-intervention response proportions for these items (Table 3).

**Table 3:** Distribution (%) of girls in the experimental (n=68) and control (n=68) colleges on a three-category scale on control beliefs items, before and after interventions.

| Experimental College | | | | |
|---|---|---|---|---|
| **Items** | **% by category** | | | **P-value*** |
| **I would feel able to consume at least 85g of iron-rich foods (IRF) per day even if I think it can make me fat** | **Rather/Strongly disagree** | **Neither disagree nor agree** | **Rather/Strongly agree** | |
| Before interventions | 57 | 12 | 31 | |
| After interventions | 31 | 6 | 63 | |
| | | | | 0.001 |
| **I would feel able to consume at least 85g of IRF per day even if I am not able to prepare IRF myself** | **Rather/Strongly disagree** | **Neither disagree nor agree** | **Rather/Strongly agree** | **P-value*** |
| Before interventions | 53 | 15 | 32 | |
| After interventions | 27 | 13 | 60 | |
| | | | | 0.04 |
| **Control College** | | | | |
| **Items** | **% by category** | | | **P-value*** |
| **I would feel able to consume at least 85g of IRF per day even if I think it can make me fat** | **Rather/Strongly disagree** | **Neither disagree nor agree** | **Rather/Strongly agree** | |
| Before interventions | 31 | 13 | 56 | |
| After interventions | 18 | 29 | 53 | |
| | | | | 0.051 |
| **I would feel able to consume at least 85g of IRF per day even if I am not able to prepare IRF myself** | **Rather/Strongly disagree** | **Neither disagree nor agree** | **Rather/Strongly agree** | **P-value*** |
| Before interventions | 32 | 15 | 53 | |
| After interventions | 22 | 22 | 56 | |
| | | | | 0.326 |

## Environmental barriers

In the experimental college, about three quarters of the girls (72%) responded that it was unlikely/very unlikely that the high price of IRF would prevent them from consuming at least 85g per day as compared to 28% before interventions (Table 4). The difference between proportions before and after interventions was significant. In the control college, there was no significant difference in the distribution of answers for this item before and after interventions. More than half of the girls (62%) in the experimental college responded that it was unlikely/very unlikely that the low physical accessibility of good tasting IRF would prevent them from consuming at least 85g per day after as compared to 35% before interventions, whereas in the control college, 24% of the girls responded unlikely/very unlikely to this item after as compared to 58% before interventions (Table 4). Proportions of pre- and post-intervention responses for this item were significant in both colleges.

**Table 4:** Distribution (%) of girls in the experimental (n=68) and control (n=68) colleges on a three-category scale of selected environmental barriers, before and after interventions.

| Experimental College | | | | |
|---|---|---|---|---|
| **Items** | **% by category** | | | **P-value*** |
| **The high price of iron-rich foods (IRF) may prevent me from consuming at least 85g of IRF each day** | **Slightly/Very** | **Neither likely nor unlikely** | **Slightly/Very** | |
| Before interventions | 28 | 7 | 65 | |
| After interventions | 72 | 4 | 24 | |
| | | | | <.001 |
| **If good tasting IRF are not sold near the school it may prevent me from consuming at least 85g of IRF per day** | **Slightly/Very** | **Neither likely nor unlikely** | **Slightly/Very** | **P-value*** |
| Before interventions | 35 | 7 | 58 | |
| After interventions | 62 | 6 | 32 | |
| | | | | 0.008 |

| Control College | | | | |
|---|---|---|---|---|
| **Items** | **% by category** | | | **P-value*** |
| **The high price of IRF may prevent me from consuming at least 85g of IRF each day** | **Slightly/Very unlikely** | **Neither likely nor unlikely** | **Slightly/Very** | |
| Before interventions | 34 | 3 | 63 | |
| After interventions | 16 | 19 | 65 | |
| | | | | 0.06 |
| **If good tasting IRF are not sold near the school it may prevent me from consuming at least 85g of IRF per day** | **Slightly/Very** | **Neither likely nor unlikely** | **Slightly/Very** | **P-value*** |
| Before interventions | 58 | 7 | 35 | |
| After interventions | 24 | 25 | 51 | |
| | | | | <.001 |

## Intention

After interventions, 90% of girls in the experimental college reported that they intended to consume at least 85g of IRF per day as compared to 83% before interventions (p<0.001, results not shown in Tables). In the control college, the difference between the proportions before (74%) and after (82%) interventions was not significant (p=0.345).

### Consumption of IRF

In the experimental college, after the interventions, the average daily consumption of all IRF during the last seven days prior to the survey was estimated at 82±46g per day which comprised in average, 24g of fish, 21g of meat, 17g of eggs, 10g of chicken, 7g of liver and 1g of shellfish. This average daily intake of IRF was approximately 40% higher (p<0.001) than the pre-intervention intake (Table 5). The average IRF intake from sandwiches (sold near the college) was 29g per day, or 35% of the total average, compared with 20g per day, or 32% before interventions (p=.033).

As for the control group, the average daily consumption of all IRF during the last seven days prior to the survey was estimated at 58±26g per day, i.e. 20g of fish, 16g of meat, 14g of eggs, 5g of chicken, 3g of liver and 0g of shellfish. No significant change was observed between average daily consumption of IRF before and after interventions (Table 5). Moreover, in the experimental group, the proportion of girls with an estimated intake of IRF greater than or equal to the 84g per day as recommended for animal protein sources by the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems [24] was more than double after (36%) as compared to before (16%) interventions (p=0.018). In the control college, this proportion was virtually the same before (19%) and after (20%) interventions (p=0.411, Figure 1).

**Table 5:** Mean daily consumption (g/day) of all IRF of adolescent girls in the experimental (n=68) and control (n=68) colleges, before and after interventions.

| Group | Means ±DS daily consumption (g/day) of all IRF | | P-value* |
|---|---|---|---|
| | Before interventions | After interventions | |
| Experimental college | 58±32 | 82±46 | < .001 |
| Control college | 57±34 | 58±26 | 0.559 |

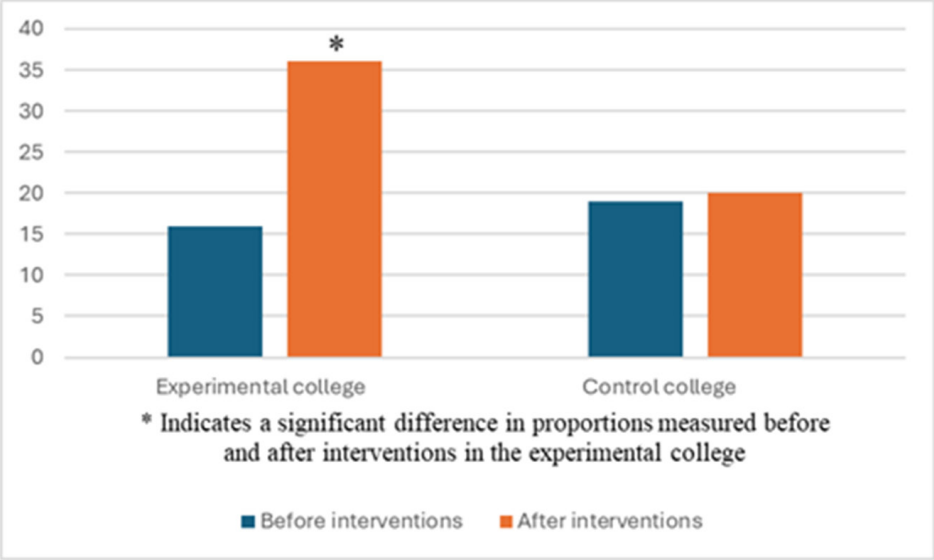


**Figure 1:** Proportions (%) of girls with average daily consumption (g/day) of all IRF combined ≥84g in experimental and control colleges, before and after interventions (n=68).

## Discussion

In this paper, results of the use of IM to develop and implement interventions among adolescent girls to improve their IRF consumption are presented. Using theory-based behavior change techniques, these nutrition interventions addressed selected psychosocial (behavioral and control beliefs) and environmental factors that may influence IRF consumption, which had been previously identified in the need assessment step (unpublished data). Identifying and addressing barriers has been shown to improve the effectiveness of interventions [28].

In this study, main barriers to the adoption of the target behavior were related to the behavioral belief that IRF can cause weight gain, control beliefs about the low perception of girls with regards to their abilities in cooking IRF and environmental issues related to the physical and financial accessibility of IRF. Nutrition education and model-based learning (cooking session) were specifically chosen to address behavioral and control belief barriers. As for environmental barriers, we collaborated with one of the vendors near the school (chosen by the girls) so that she could provide affordable iron-rich meals to girls. It should be noted that adolescent girls in the experimental college were actively engaged in the process of developing and implementing all interventions. They were involved in choosing objectives for change as well as intervention methods and activities. In addition, they participated in large numbers in all different activities.

In the experimental college, nutrition education appears to have improved girls' knowledge on the importance of IRF consumption and demystify the belief related to weight gain associated with their consumption. In fact, more than half of the girls no longer perceived the daily IRF consumption as something that could lead to weight gain, a proportion that nearly doubled as compared to before interventions. This finding is consistent with those of Hajivandi et al. [29] who showed that the implementation of an educational intervention program that emphasized the importance of healthy nutritional behaviors and the impact of these behaviors on health and well-being enhanced positive beliefs about healthy nutritional behaviors among Iranian adolescent girls aged 15-21 years (N=72).

Control beliefs of adolescent girls in the experimental college improved significantly after interventions. In our context, practice incentive activities may have increased girls' confidence in their ability to cook IRF and their perseverance when facing difficulties to do so, so girls have more control over the behavior [30,31]. Again, these results are in line with those of Hajivandi et al. [29] who have shown that developing competencies necessary to practice healthy nutritional behaviors (through interactive discussion, presentation of successful role models among peers, and practical exercises) significantly improved control beliefs related to nutritional health behaviors among Iranian adolescent girls.

In addition, after interventions, a lower proportion of girls in the experimental school perceived price and physical accessibility of IRF as a barrier to their daily consumption. The importance of affordability has been highlighted in numerous studies that have indicated that price influences adolescents' purchases and selection of healthy nutritious foods [32-35]. Qualitative research has indicated that improving physical access to healthy foods was perceived by adolescents as a motivating factor to their consumption [21-36]. Several studies reviewed by Krølner et al. [32] reported that nutrition interventions should consider different dimensions of healthy food availability in the school environment, such as presence, variety, visibility, quality and cost.

As part of our interventions, to improve the affordability of IRF, a meal vendor near the school was involved, and a financial support was provided to her so that she could offer affordable iron-rich meals to girls. A meta-analysis of intervention studies showed the effectiveness of subsidies in increasing healthy food consumption among adolescents [14]. After the interventions in the experimental group, the amount of IRF eaten in the form of a sandwich (subsidized food increased in absolute amounts, but other forms of IRF such as rice with meat or fish (non-subsidized foods) also did. This suggests that the subsidy granted to the vendor in the experimental college was effective in promoting consumption of IRF, but also that the other participatory interventions were presumably effective, since the consumption of all forms of IRF increased significantly.

In Benin, Alaofè [37] developed a nutrition intervention to improve the iron status of adolescent girls by increasing the physical accessibility of IRFs. The intervention consisted of making changes in the school cafeteria by increasing the number of animal-based foods offered in the menu. At the end of the study, the menu was more diversified and of better nutritional quality and girls significantly increased their mean dietary and absorbable iron intakes. The authors also showed that nutritional interventions aiming at increasing dietary iron intake and bioavailability through nutrition education and increasing bioavailable iron in the food supply improved iron status and significantly decreased the prevalence of iron deficiency anemia in Beninese adolescent girls [37].

In the present study, the intention to consume at least 85g of IRF per day increased significantly among girls of the experimental college after interventions. These findings concur with those of Hajivandi et al. [29] who showed that after the implementation of an educational intervention program based on the TPB, intention to adopt healthy nutritional behaviors increased among adolescent Iranian girls. After the implementation of all participative interventions, a higher proportion of girls in the intervention college was consuming more than 84g of IRF on a daily basis and the mean intake of IRF doubled. As expected, no change was observed among girls of the control college. These results are also in line with those of Hajivandi et al. [29] who showed that after the implementation of a nutrition intervention program, adolescents' girls in the intervention group increased their consumption of fruits and vegetables, milk and milk products, meat, seafood, legumes and eggs. In their setting, the intervention program activities included nutrition education sessions, interactive discussions, peer-to-peer modeling of success, and practice of healthy nutrition behaviors.

In our study, the increased IRF consumption measured after participative interventions may have many positive health impacts.

According to WHO [2], improving dietary habits and bioavailable iron intakes of adolescents increases their iron stores and reduces the prevalence of anemia and iron deficiency anemia. Therefore, it would help to increase resistance to infections, reduce metabolic disorders, physical and psychomotor developmental delays or abnormalities caused by iron deficiency in adolescents, in addition to ensuring optimal iron stores for eventual pregnancy in adolescents. As reported by Hargraves et al. [14], nutritional interventions initiated during adolescence provide the foundation for a healthy start in life for the next generation.

### Strengths and limitations

The main strength of this study is the use of the IM to develop effective interventions to improve IRF consumption among Senegalese adolescents which target modifiable determinants and defined specific behavior changes interventions. The involvement of adolescent girls and relevant stakeholders throughout the entire IM process was likely key to the success of interventions. The study describes in detail the development of behavior changes interventions based on the application of BCTs and their impacts on target behavior. Our study also has some limitations. First, colleges were purposively selected and all girls attending specific classes were invited to participate. Therefore, our results cannot be generalized to all adolescents attending other colleges in Dakar city or in rural areas. Also, the context of the interventions (school setting) did not include out-of-school adolescents. Finally, the evaluation was carried out just after the implementation of interventions due to school calendar constraints, whereas it could be considered over a longer period of time in order to better assess the impact of the interventions over the long term and their sustainability.

## Conclusion

This study shows that the use of the IM process to design, implement and assess interventions targeting specific behavioral and control beliefs as well as environmental barriers represents a promising approach to increase the consumption of IRF among urban adolescent girls in Senegal. Attention to individual and environmental factors underlying adolescents' eating behavior seems relevant in order to design effective nutrition interventions that can improve their nutritional status. In the future, experimental studies with larger samples size that would include the rural setting may help to better establish the effectiveness of the interventions. Also, studies over a longer period could verify the impact of the interventions in the long term and its sustainability.

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