Agriculture & Food Security

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Assessing the impact of a personalised application-based nutrition intervention on carbohydrate intake in rural Benin

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Abstract

Background This study aims to assess the effect of a personalised nutrition intervention on nutrient intake in rural Benin as a tool to tackle the double burden of malnutrition. The personalised recommender system uses information from the eating behaviour of all household members combined to provide tailored advice on adjusting the consumption of up to three food items to tackle malnutrition and obesity in the household. Many developing countries nowadays experience the double burden of malnutrition, the coexistence of undernutrition alongside overweight and obesity, as well as other related non-communicable diseases. Personalised nutrition was very effective in European studies in improving nutrition and tackling obesity, which is why this study aims to translate personalised nutrition to a developing country context.

Results A study was conducted in rural areas of Benin where 720 households were randomly selected. Due to high attrition, we used propensity score matching and looked into average treatment effects. We found that the recommendation to eat less carbohydrates resulted in a reduction in carbohydrate consumption with a significant effect for both the average treatment effect (ATE) of the whole population as well as the average treatment effect of the treated (ATET). We found that households that received the treatment to consume less food items with a high carbohydrate intake have followed this advice and have consumed on average lower levels of carbohydrates than their control counterparts.

Conclusions Rising obesity is a worldwide problem that poses a severe challenge for policymakers. Especially in developing countries the change from too little, to too much is seamless. For the increasing obese population, the recommender system could be a useful tool. The idea of personalised nutrition has the potential to be one of the necessary steps in the ongoing battle against obesity and unhealthy diets. The personalised application-based recommender system used in this study has the ability to be a strong and effective tool for policymakers in the ongoing battle of food security vs. obesity in Benin and other countries. We propose that future research focuses more on personalised nutrition in the context of a developing country.

Keywords Double burden, Nutrition security, Intervention study, Personalised nutrition, Carbohydrates, Africa, Benin

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Introduction

This paper studies an innovative approach to deal with the double burden of malnutrition and improve overall nutrition in a society, which is called personalised nutrition advice. It works in a way that is specific to the person's diet. Recommendations are made to improve the intake of food and hence nutrition. This topic is extremely important as the increasing rate of overweight and obesity has been an alarming worldwide trend. Obesity rates have tripled since 1975. Overweight and obesity are major risk factors for a number of chronic diseases, including cardiovascular diseases such as heart disease and stroke, which are the leading causes of death worldwide. Being overweight can also lead to diabetes and its associated conditions, including blindness, limb amputations, and the need for dialysis [34]. The impact on the health status of the population is severe and there is a strong need for appropriate interventions to tackle this problem. This global issue also affects developing countries. However, the situation in developing countries is different as undernutrition and over nutrition can be observed at the same time, which makes effective interventions even harder to realise. In a review of the status of nutrition in Benin, it was reported that a double nutritional burden with over 30 percent stunted children and 7 percent obese adults was observed based on a large study with almost 7000 participants [14]. Other studies have looked at different population groups, like women of childbearing age, Darboux et al. [9] or school children, Azandjeme et al. [2] with lower number of participants, both around 200 each. Both studies reported the prevalence of underweight, malnutrition and overweight in the same population group, which stresses the need for targeted advice as even in the same population group differences in nutritional status are large.

The Beninese population faces a shift in nutritional patterns associated with increased development of diet-induced diseases, which is sometimes referred to as a nutrition transition [10, 24, 26]. This nutrition transition is mainly associated with a shift from a predominance of undernutrition and the presence of malnutrition (vitamin deficiency, protein-calorie malnutrition, mineral deficiencies) to higher rates of overweight and obesity. This co-occurrence of undernutrition and over nutrition, in particular overweight and obesity is described as the 'double burden' of malnutrition [33].

While the traditional Beninese diet is high in grains and fruits, the upcoming transitional diet is rich in white bread, pasta, local roots, nuts, meat, milk products, fat and sweets. The advantage of the transitional diet compared to the traditional Beninese diet is its higher diversity and higher micronutrient adequacy [24]. However, higher diversity is not always associated with a higher healthfulness score of the overall diet, potentially due to higher intake of saturated fat and sugar [24]. In agreement with this notion, the results from a FAO study, covering the period from 2014 to 2016, showed that the Beninese average dietary energy consumption is higher than the estimated requirements [12]. This may also explain the observed trend towards increased obesity rates.

In addition, it has been found that women in Benin were more prone to obesity than men [14]. The latest data from 2016 on the body weights of Beninese women showed that 30 per cent were overweight, with 10 per cent being obese [21]. Despite the nutritional transition, Benin still encounters problems with undernutrition, with 8 per cent of women being underweight [21]. Anaemia affects about 58 per cent of children and 41 per cent of women [28]. Moreover, a study of Beninese children classified only 2 per cent as overweight, 5 per cent as at least moderately wasted, and 34 per cent as at least moderately stunted [31]. In Benin, about 15 per cent of the inhabitants of rural areas and 7 per cent in urban areas experience food insecurity, showing a clear difference between these two population groups [11].

As one can observe there are different needs in terms of nutrition and intervention within the same country and the same population group. While some factors, like location or gender, might play a role in determining the likelihood of obesity or malnutrition, there are also many other factors that can play a role and to implement just one nutritional programme might not help to better understand the overall nutritional status. Targeted, specific and personalised advice is needed to tackle the health and nutritional status of the individual, and to further target the obesity on the one hand and the malnutrition on the other.

Access to adequate food supply in rural areas is highly related to farm productivity [4, 20]. With most of the rural poor earning their income through agriculture, they heavily rely on the performance of their farms to provide an adequate diet, either by consuming their own harvest or by purchasing food items using the income generated from selling their harvest. However, poorly developed and inefficient market structures might hinder access to nutritious diets even during times of good harvest [17, 28]. Sibhatu et al. [23], found that in developing countries production diversity and market access are highly associated with a diverse diet at the household level. An increase in production diversity might enable rural farm households to maintain a balanced, self-sustained energy and nutrient supply, as a positive association between production diversity and nutrient adequacy has already been demonstrated in several studies [1, 29, 30]. In Benin, the national dietary guidelines

(Benin's Food Guide to Healthy Eating) provide easily comprehensible information on a balanced diet (Conseil National de L'Alimentation et de la Nutrition) [8]. These guidelines can be found in the Annex of this paper and are in form of a traditional Beninese hut. The base of the hut, and hence the base of the nutrition recommendation, includes cereals and tubers, while on the top of the hut comes meat, fish, beans and other proteins. In green, you will find the roof of the house with vegetables, followed by fruits. These food groups are building up a healthy Beninese diet and are given as free advice from the ministry of food and nutrition in Benin. Such generic, written advice seems to not have a large impact when one considers the diversity in the population, ranging from undernutrition to over nutrition. Additionally the availability of diverse food items and habits and the spread of information and illiteracy can be problematic. The pan-European Food4Me[1] study showed that advice tailored to individual characteristics was more effective in promoting a sustainable healthy lifestyle[2] than generic guidelines. This concept is known as 'personalised nutrition' and aims at improving the perceived relevance of dietary advice, thus, leading to increased motivation and attention to a healthy lifestyle [7].

Golzarand et al. [15] studied personalised nutritional advice in developing countries and its impact on dietary decisions in the Middle East and North Africa. The study revealed a nutritional shift towards a 'Westernised diet' and it was suggested that personalised nutritional education might support healthy diets and decrease the rising burden of chronic diseases. However, personalised nutritional advice was mainly targeted to certain population groups under selected conditions (for example, HIV-positive children in Tanzania with a high rate of undernutrition due to infrequent meals and poor dietary diversity). In that case, it was proposed that personalised nutritional advice can help to educate households to efficiently use available foods to accommodate the special nutritional demands of HIV-positive children [6, 27]. In addition, a nutrition education programme involving local advisers in South Africa successfully improved the weight status of children younger than 5 years old, but it was not possible to achieve normalised growth of stunted children up to two years of age [32].

While personalised nutrition advice in developing countries can more effectively promote healthy lifestyle patterns, it has only been applied in limited cases targeting specific population groups with underlying health conditions and without accounting for the socioeconomic characteristics of the communities and to our knowledge it has not been done in Benin. The purpose of this paper is to shed light on how personalised nutrition advice offered to households in rural communities of Benin could more effectively foster a healthier lifestyle compared to the generic advice offered by the national dietary guidelines. In this study, we designed and performed a nutrition study on the effects of personalised nutritional advice on the intake of specific micro- and macro-nutrients in rural areas of Benin while accounting for the effects of farm production diversity, market distance and other factors influencing nutrition and nutritional behaviour. We studied whether personalised nutrition advice offered to rural Beninese households can lead to an improved intake of micro- and macronutrients due to corresponding recommendations. As literature and several studies have shown, general nutrition advice may not be suitable and that the double burden of nutrition persists in many developing countries, such as Benin. In this study, we want to investigate if personalised nutritional advice can make a difference in this problem and whether this could be the way forward in tackling the issue of the double burden of malnutrition.

The remainder of this paper is organised into four sections. The second section presents the methodology used in this study and section three offers a description of the data employed in the empirical model along with the specifications and the estimation of the empirical model. The fourth section includes the discussion of the main results, summarises the main conclusions and offers the policy implications of this study.

Methodology

Sampling procedure

The study was designed in a research collaboration between the Technical University of Munich (TUM) and the National Agricultural Research Institute of Benin (INRAB). It was initially designed as a randomised control trial of rural households in Benin. From a set of representative villages that was provided by INRAB, 48 villages were selected to be equally distributed over all eight agro-ecological zones of Benin (DPP (Directorate of Planning and Forecasting)/MAEP (The Ministry of Agriculture, Livestock and Fisheries), 2001), leading to 6 villages per zone. As the target population were farmers, these were rural villages. In each village, 15 households were randomly selected from the census list,[3] making up a total of 720 households. All members of the household were included in the study. To ensure that the villages

[1] http://www.food4me.org/.

[2] As defined by the WHO https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle.

[3] Provided by INRAB.

where similar, two villages were randomly selected in each district and one of these was randomly assigned as an intervention village, while the other one was a control village. These two villages were located in different counties to minimise spill-over effects while still being in the same district to maximise the similarity between the villages.

While the study was initially set up as a randomised control trial, unfortunately, we had attrition problems with a high dropout rate due to the remoteness of some of the villages, as well as the fact that there were four different points in time where data were collected. If a household did not participate in one of those, they were disregarded for this study. To address any biased results stemming from the attrition, we deployed a matching method prior to the final estimations of our model.

Due to the setup of the project, participating households had to meet the following two requirements: (i) the household had to have at least three members, including one man and one woman 18 years or older and one child 5 years or younger, and (ii) agriculture had to be the main source of income. The participating households were surveyed regarding their nutrition, health, agriculture and socio-economic situation. In each household, the head of the household and the person in charge of cooking were interviewed simultaneously through separate enumerators at different locations. The head of the household answered questions about the agricultural production system and the health and education level of the family.

The person in charge of cooking reported which foods were consumed during the previous month based on a qualitative Food Frequency Questionnaire. As all meals are commonly eaten together and it was very hard to estimate quantities for each person separately, the person in charge of cooking reported for the whole household, including all age categories. All dietary information was taken at household level.[4] If a particular food item had been consumed, the interviewee had to estimate how much (in grams) was consumed in the last 24 h based on recall. Kitchen scales were provided to the enumerators to facilitate food quantification. The 360 households in the control villages were given generic advice on healthy nutrition from Benin's Food Guide to Healthy Eating (CAN) (see ANNEX A), while the other 360 households in the treatment villages received personalised advice via the recommender system (see Section below).

The Beninese authorities ethically approved this study procedure.

Data collection and variable description

The recommender system used age and gender information from all family members, 24 h recall information on food consumed, and a qualitative Food Frequency Questionnaire for the whole household as input. The personalised recommendations were developed by comparing the estimated nutrient intake of the household with the intake reference values considering all household members. The nutrient intake information was calculated based on 24 h recall data using the West African Food Composition Table [25], which provides macro- and micro-nutrient amounts for West African food items. The intake reference values for the household were calculated first for each household member individually using gender and age information and, then, summed up for the whole household. We acknowledge that it would be better to have consumption per family member, but as food is cooked for all household members together and is shared and consumed together, we found the risk of over and underestimation too great. Especially given the fact that most households consist on average of 9 to 10 household members.

Reference values for the individual energy intake per person were obtained from FAO, with physical activity levels equivalent to a vigorous lifestyle, as it involves non-mechanised agricultural work, collecting water and non-mechanised housework, which are usual daily activities for the households in this survey [13]. The reference values for nutrient intake were calculated taking gender and age into account using the Recommended Dietary Allowances (RDA) [18][5] from the Food and Nutrition Board, Institute of Medicine (IOM), United Stated of America (Institute of Medicine). The IoM recommendations were selected because their estimations include the Afro-American population, and to the best of our knowledge, there is no database of West African recommended dietary intake of micronutrients. The amount of energy and nutrients calculated as needed was compared to the values calculated from the food consumption.

The nutrients that showed the highest deviation between actual and recommended intake were identified as critical for the purposes of this study. Up to three food items with high density of these critical nutrients were recommended to be consumed either more or less. Those food items were taken from the Food Frequency Questionnaire. The recommended food items had to be

[4] We decided to focus on the household level as food is commonly consumed together and there is little snacking or outside eating. We also wanted to avoid too much guessing, as is easier to remember how many full hands of a product were used in the whole cooking process then it is to estimate split up by each member of the household. Especially as households on average had nine household members.

[5] the values can be found here: https://ods.od.nih.gov/HealthInformation/Dietary_Reference_Intakes.aspx.

consumed by the household within the last month, as we wanted to make sure that households had access to the food items and they were neither disliked nor there were any allergies. The underlying assumption is that if a food item was not consumed in the last months, there might be a reason for this. For example, non-availability, price or a simple dislike by the household members and that even if that food item was recommended this recommendation would not be taken into consideration. The recommendation was offered as an increase or a decrease in consumption of that food item, while specific quantities were not provided. Macronutrients—fat, carbohydrates and protein—were recommended for an increased or a decreased consumption depending on the actual intake of the household.

Next to food consumption, several other variables are of importance to this study. We also included information on market distance (in minutes of walking time), the family size and illness (nutrition related[6]) in the family at t_1–before intervention [16, 23]. Family size indicates the number of people with whom the food had to be shared within the same household, while a health indicator for nutrition-related diseases has also been taken into consideration to capture any nutrition problems in the family. In addition, the covariate market distance was used to capture the availability of food items that could not be produced by the household. The amount of credit the household borrowed, as well as the salary they earned in off-farm employment, were also taken into account. Those could indicate additional income that could be used for food purchases. The hours worked in off-farm employment were also used as a proxy for the amount of time spent away from the family. Finally, we included the age of the household head and his/her literacy level. Individuals were classified as literate if they were able to read and/or write and illiterate if they could do neither.

Analysis

To assess whether the intervention had the anticipated impact, we focused on all the nine micronutrients and all three macronutrients that were recommended during the study (as described above). We considered nutrient intakes as percentages of recommended intakes (i.e. relative nutrient intakes). For example, a relative vitamin A intake of 80 per cent refers to a household that consumed 80 per cent of the reference value (RDA) of vitamin A through food consumption in the past 24 h. Using the treatment effects model, we want to assess the outcome of the untreated population if they would have received treatment and for the treated population it assumes the outcome if they would have not received the treatment.

Due to attrition problems, we had to ensure a match between the treated and control households using the propensity score matching (PSM) approach, constructing a comparison group by matching two similar households based on their propensity scores in the population of non-participating groups. Propensity scores specify a conditional probability of applicants participating in a programme when observable characteristics of applicants are given. PSM allows us to solve selection bias issues, get non-biased estimates of the treatment effect and compare the factual and counterfactual to estimate the outcome of a programme. Rosenbaum and Rubin [22] first introduced the PSM approach, with Becker and Ichino [3] and Caliendo and Kopeinig [5] later on providing some improvements and more applications.

For the matching purposes of this study, we used Eq. (1) to match control to intervention households:

$$\text{Propensity scores} = P(X) = \Pr(T = 1|X). \tag{1}$$

To account for diversity in agricultural production, we included as covariates in Eq. (1): the crop variety (i.e. how many different crops were produced within the household) and the tropical livestock units (TLU) with one TLU being equivalent to 250 kg of live animal weight [19]. Both of these variables indicate access to food items at household level. Soil quality and rainfall were also used as covariates as they give an indication of the possibility to produce nutritious outputs, both variables are self-reported on a scale of 1 to 10 with 1 being the worst and 10 being the best outcome.

For the Treatment effect, we differentiate between an Average Treatment Effect (ATE) and an Average Treatment effect of the Treated (ATT). The ATE is defined in Eq. 2 and compares the expected carbohydrate intake for households (i) that received treatment (Y_1) against the households that did not receive treatment (Y_0), while the ATT only looks at the treated group and compares the expected outcome without treatment to the expected outcome with treatment only for this subgroup:

$$\text{ATE} \quad E[Y_{i1} - Y_{i0}], \tag{2}$$

$$\text{ATT} \quad E[Y_{i1} - Y_{i0}|T = 1]. \tag{3}$$

Households were assigned unique identification numbers. For data analysis, households were included if (1) they took part in the nutritional as well as the agricultural and socio-economic questionnaires; (2) at least one member of the household was consistently present during the different time points of the study. Out of 720 households included in the study, 487 fulfilled these

[6] Households were asked about illnesses that can be attributed to food consumption, like diarrhoea, night blindness or diabetes type II.

Table 1 Descriptive statistics of the control and intervention group

Variable name	Control group ($n=252$)	Intervention group ($n=235$)	p-value of t-test	Less carbohydrates ($n=46$)
Number of crops produced	3.476 (1.748)	3.587 (1.758)	0.49	4.152 (2.43)
Distance to the market (in walking minutes)	56.623 (48.376)	62.102 (54.287)	0.24	62.173 (57.272)
Household size (number of members)	9.377 (5.753)	9.851 (5.733)	0.36	11.370 (6.252)
Age of the household head	40.377 (12.616)	41.557 (13.249)	0.31	41.826 (15.035)
Tropical livestock index (TLU)	0.108 (0.207)	0.102 (0.233)	0.76	0.135 (0.228)
Amount of credit borrowed in CFA	31,172.42 (95,104.3)	31,723.4 (75,609.41)	0.94	23,260.87 (62,184.47)
Quality of the soil (Scale from 1–10)[a]	5.317 (2.063)	5.689 (1.924)	0.04	5.630 (1.678)
Rainfall (Scale from 1–10)[b]	5.480 (1.841)	5.366 (2.053)	0.52	5.022 (1.972)
Salary from off-farm employment in CFA	126,690 (633,453.1)	72,904.68 (319,484.4)	0.24	159,934.8 (646,533.5)
Hours worked off-farm	438.587 (1231.783)	318.315 (869.457)	0.22	301.043 (888.392)
Prevalence of disease or illness associated with nutrient in the household	41.67%	31.91%	0.03	34.78%
Literacy of the household head (1: literate; 0: illiterate)	41.27%	32.77%	0.05	30.43%

Values reported in this table represent the average, while the standard deviation is included in the parenthesis

[a] With one being poor soil and ten being excellent soil

[b] With one being not sufficient or too much rain and ten being excellent rain conditions

requirements. Stata 15 was used to perform the statistical and econometric analysis.

Results

Descriptive statistics

In the sample used in this study, we have 252 households in the control group and 235 households in the intervention group. As recommendations were made according to the specific need of each household, not all households in the intervention group received the same treatment. One household might have gotten the recommendation to eat less of a food item, which contained a lot of fat, while another household might have received the recommendation to eat a food item with a lot of vitamin A, and so on. This can explain the different intervention groups depending on which advice we are looking at. The descriptive statistics for both the intervention and control group can be found in Table 1. A t-test was performed to test whether the intervention group and control group had similar descriptive statistics. For the majority of the variables there is no statistical significance between the two groups. However, for quality of the soil, literacy of the household head and health status related to nutritional diseases, there were some statistically significant differences. The soil was significantly better for households in the treatment group, there were more households with health-related diseases in the control group and the literacy was better in the intervention group.

While all micro- and macro-nutrient treatments were analysed, the recommendation to eat less carbohydrates was the only treatment that had a significant average treatment effect (ATE) and average treatment effect of the treated (ATT). For this reason, we will be reporting only on these recommendations for the rest of the study. The descriptive statistics of the intervention group that received the advice to eat less of a food item that were rich in carbohydrates can also be found in Table 1.

Treatment effects

The recommendation to eat less carbohydrates had a significant effect for both the average treatment effect (ATE) of the whole population as well as the average treatment effect of the treated (ATT). The ATE shows that there was a reduction of 19 percent in the carbohydrate intake of people that received the treatment to eat less carbohydrates. If one looks at the ATT (Table 2), it was even larger by 13 percent than for the whole population, but both are significant and show that households that received the treatment to consume less food items with a high carbohydrate intake seemed to have followed this

Table 2 Average treatment effects for the recommendation to eat less carbohydrates

Recommendation to eat less carbohydrates ($n=298$)	Coef.	Std. Err.
ATE	−19.024*	10.950
ATT	−32.509*	17.420

$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$

advice and eat on average fewer carbohydrates than their control counterparts.

Statistically significant differences between control and treated group were found for less carbohydrate consumption. The recommendation for less carbohydrate intake had the anticipated sign—negative, which translates that households that were recommended to eat less carbohydrates, ate less carbohydrates. For the other macro (fat and protein)- and micro-nutrients (calcium, folate vitamin A, B2, B3, B12, C, D, E and K) of this study, we could not find any statistically significant differences between the control and intervention group and hence excluded them from the results. In the next section, we will be comparing our findings to previous studies.

Discussion and policy implications

In this study, we analysed the effectiveness of a personalised nutritional intervention via an application-based recommender system in rural Benin. We compared changes in the nutrient intakes of the control and intervention groups. The control group received a generalised recommendation based on the Beninese healthy eating recommendation table, while the intervention group received personalised recommendations based on the application-based nutrient recommender system. Both control and intervention groups received nutritional advice in our study for ethical reasons and this was agreed upon during the ethical approval process by the Beninese authorities.

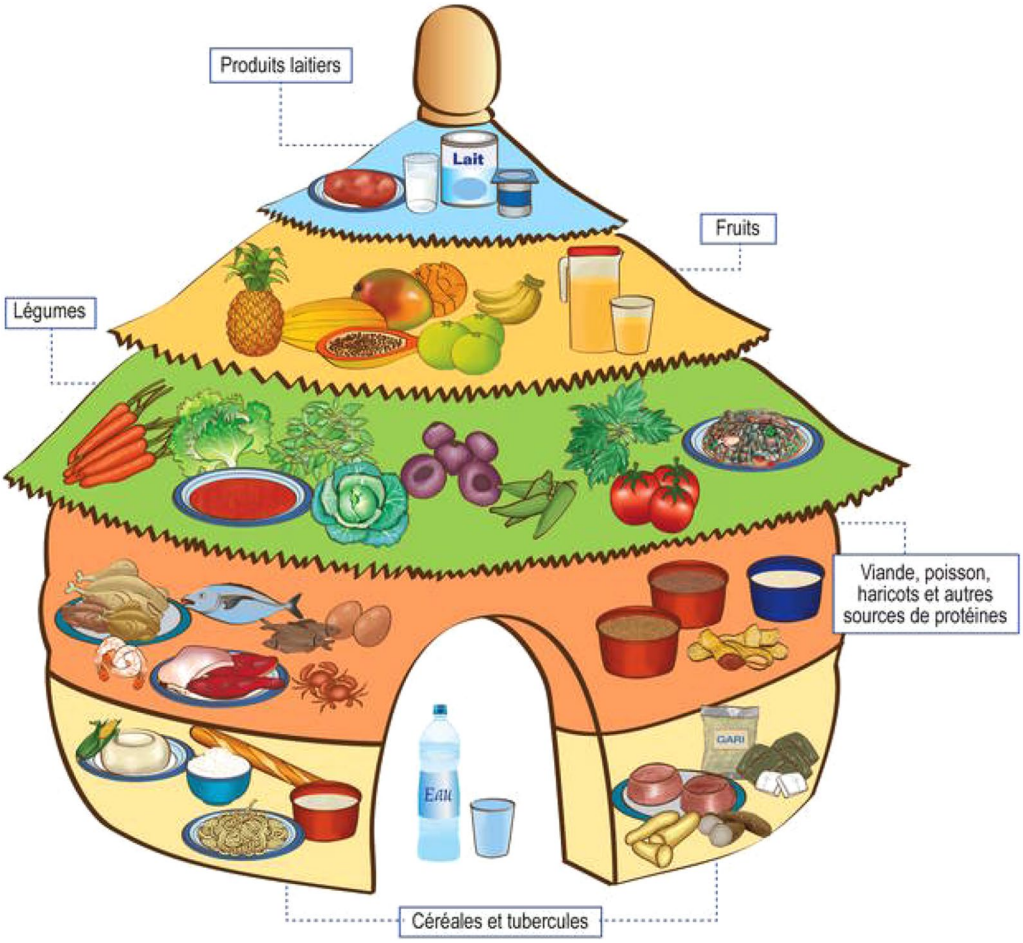
We observed a significant reduction of carbohydrate intake for the intervention group that received the recommendation to eat less carbohydrates. Thus, tailored recommendations through an application-based recommender system could potentially offer a significant improvement to the transitional diet, which is believed to include high amounts of sugar and fat [24]. Hence, moving from the traditional to the transitional diet, a successful intervention in reducing the consumption of carbohydrates could prevent obesity. However, for all other micro- and macro-nutrients we could not find significant effects.

It is possible that the recommended food items that should have increased specific vitamins were not as easily available. Additionally, it is more complex to balance micronutrients than it is to balance carbohydrates. It might also not be enough to focus on a limited set on food items or a 24 h recall. There are many reasons why we did not see the intended effects, however, we still find this a promising idea which will require future research. The battle of malnutrition and obesity is ongoing and we still believe this approach to be promising. Further research may focus more on the availability of micronutrients in the diet and how to utilise them successfully. It would also be interesting to look into the food distribution between the household members, as the personalised nutrition approach was very successful on an individual level in Europe. Individual demands, for instance, to differentiate between adults and children or between obese and undernourished members within the same household would be another pathway to look into.

The recommender system itself was solely focused on nutrition, and thus, a logical next step could be the development of a recommender system for nutrition-sensitive agriculture with a food system approach. This enhanced recommender system could analyse the health–nutrition–agriculture relationship that is clearly present, and pursue improved agricultural production as well as food consumption patterns to achieve an optimal nutrient and energy intake combined with the most effective agricultural production.

The rising obese population in developing countries and all over the world poses a severe challenge for policy makers. The diseases associated with obesity and unhealthy diets will become a great threat on the future of many countries. For the increasing obese population in Benin, and the rest of the world, the personalised recommender system could be a useful tool. The idea of personalised nutrition could be one of the necessary steps in the ongoing battle against obesity and unhealthy diets. The personalised application-based recommender system used in this study is highlighting a promising way for future research. Our study revealed that there could be a connection between personalised nutrition recommendations and obesity patterns and thus further research towards this direction could contribute in the ongoing battle of malnutrition and obesity that is a struggle all over the world.

Annex A: General nutrition advice from the Beninese authorities (CAN)



Acknowledgements
No acknowledgements.

Author contributions
LB conceptualised and designed the study, did the anaylsis and data interpretation and drafted the work. SK conceptualised and designed the study and prepared the data. MV interpreted the results and revised the written work. GAK, HA and KG designed the study. GFC and PH set up and performed the data collection. JS revised the study.

Funding
Open Access funding enabled and organized by Projekt DEAL. There are no funding sources to report.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was granted by the Beninese authorities. All participants in this study agreed to participate.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interest.

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Received: 8 February 2022 Accepted: 30 December 2023
Published online: 01 April 2024

References

1. Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels MC, Deitchler M, et al. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. J Nutr. 2010;140(11):2059S-2069S. https://doi.org/10.3945/jn.110.123414.
2. Azandjeme CS, Alihonou F, Sossa CJ, Gbatcho U, Gounongbe F, Makoutode M, Agueh VD. Factors associated with the nutritional status of schoolchildren in the main city of Benin Republic, Sub-Saharan Africa. Int Archiv Public Health Commun Med. 2020. https://doi.org/10.23937/2643-4512/1710036.
3. Becker SO, Ichino A. Estimation of average treatment effects based on propensity scores. Stata J. 2002;2(4):358–77. https://doi.org/10.1177/1536867X0200200403.
4. Bezu S, Kassie GT, Shiferaw B, Ricker-Gilbert J. Impact of improved maize adoption on welfare of farm households in Malawi: a panel data analysis. World Develop. 2014;59:120–31.
5. Caliendo M, Kopeinig S. Some practical guidance for the implementation of propensity score matching. J Econ Surveys. 2008;22(1):31–72. https://doi.org/10.1111/j.1467-6419.2007.00527.x.
6. Celis-Morales C, Livingstone KM, Marsaux CFM, Forster H, O'Donovan CB, Woolhead C, et al. Design and baseline characteristics of the Food4Me study: a web-based randomised controlled trial of personalised nutrition in seven European countries. In Genes & nutrition. 2015;10(1):450. https://doi.org/10.1007/s12263-014-0450-2.
7. Celis-Morales C, Livingstone KM, Marsaux CFM, Macready AL, Fallaize R, O'Donovan CB, et al. Effect of personalized nutrition on health-related behaviour change: evidence from the Food4me European randomized controlled trial. Int J Epidemiol. 2016;46(2):578–88.
8. Conseil National de L'Alimentation et de la Nutrition: Guide alimentaire du Bénin. http://poledfn.org/wp-content/uploads/2014/03/guide_alimentaire_benin_legal.pdf, Accessed 30 July 2018.
9. Darboux AJ, Agueh V, Santos RY. Assessment of the nutritional status and dietary intake of women of childbearing age in the city of Comè, Benin. Pan Afr Med J. 2022. https://doi.org/10.11604/pamj.2022.41.350.33393.
10. Food and Agriculture Organization of the United Nations. Nutrition country profiles: Benin summary. 2018a. http://www.fao.org/ag/agn/nutrition/ben_en.stm, Accessed 17 July 2018.
11. Food and Agriculture Organization of the United Nations: FAO BENIN–Cadre de Programmation Pays (2012–2015). 2018b. http://www.fao.org/3/a-i4401f.pdf. Accessed 17 July 2018.
12. Food and Agriculture Organization of the United Nations (2018c): FAOSTAT-Benin, Average dietary energy supply adequacy (%) (3 year average), 2014 to 2016. updated on 7/18/2018 http://www.fao.org/faostat/en/#data/FS. Accessed 22 Aug 2018.
13. Food and Agriculture Organization of the United Nations; United Nations University; World Health Organization: Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation: Rome, 17–24 October 2001: Food and Agricultural Organization of the United Nations. 2004. https://books.google.de/books?id=8WW7LP5h6usC.
14. Gbary AR, Kpozehouen A, Houehanou YC, Djrolo F, Amoussou MPG, Tchabi Y, et al. Prevalence and risk factors of overweight and obesity: findings from a cross-sectional community-based survey in Benin. Global Epidemic Obesity. 2014;2(1):3. https://doi.org/10.7243/2052-5966-2-3.
15. Golzarand M, Mirmiran P, Jessri M, Toolabi K, Mojarrad M, Azizi F. Dietary trends in the Middle East and North Africa: an ecological study (1961 to 2007). Public Health Nutrit. 2012;15(10):1835–44. https://doi.org/10.1017/S1368980011003673.
16. Harris J. Gender Implications of Poor Nutrition and Health in Agricultural Households. With assistance of Agnes R. Quisumbing, Ruth Meinzen-Dick, Terri L. Raney, André Croppenstedt, Julia A. Behrman, Amber Peterman. Dordrecht: Springer Netherlands (Gender in Agriculture). 2014.
17. Hoddinott J, Headey D, Dereje M. Cows, missing milk markets, and nutrition in rural Ethiopia. J Develop Stud. 2015;51(8):958–75.
18. IOM, Institute of Medicine: Health and Medicine Division (HMD): Health and Medicine Division. http://www.nationalacademies.org/hmd/. Accessed 29 Jan 2018.
19. Jahnke HE. Livestock production systems and livestock development in tropical Africa: Kieler Wissenschaftsverlag Vauk Kiel. 1982: 35.
20. Kirk A, Kilic T, Carletto C. Composition of household income and child nutrition outcomes evidence from Uganda. In World Development. 2018;109:452–69.
21. Nutrition Landscape Information System (2018): Country Profile Benin. World Health Organization. http://apps.who.int/nutrition/landscape/report.aspx?iso=ben, Accessed 30 July 2018
22. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika. 1983;70(1):41–55. https://doi.org/10.1093/biomet/70.1.41.
23. Sibhatu KT, Krishna VV, Qaim M. Production diversity and dietary diversity in smallholder farm households. Proceed Nat Acad Sci. 2015;112(34):10657–62.
24. Sodjinou R, Agueh V, Fayomi B, Delisle H. Dietary patterns of urban adults in Benin: relationship with overall diet quality and socio-demographic characteristics. Eur J Clin Nutrit. 2007. https://doi.org/10.1038/sj.ejcn.1602906.
25. Stadlmayr, Barbara. West African food composition table. Table de composition des aliments d'Afrique de l'Ouest. Rome: Food and Agriculture Organization of the United Nations. 2012
26. Steyn NP, McHiza ZJ. Obesity and the nutrition transition in Sub-Saharan Africa. Anna New York Acad Sci. 2014;1311:88–101. https://doi.org/10.1111/nyas.12433.
27. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: a call for tailored nutrition training. PLoS ONE. 2014. https://doi.org/10.1371/journal.pone.0098308.
28. Thorne-Lyman AL, Valpiani N, Sun K, Semba RD, Klotz CL, Kraemer K, et al. Household dietary diversity and food expenditures are closely linked in rural Bangladesh, increasing the risk of malnutrition due to the financial crisis-3. J Nutrit. 2009;140(1):182S-188S.
29. Tontisirin K, Nantel G, Bhattacharjee L. Food-based strategies to meet the challenges of micronutrient malnutrition in the developing world. Proceed Nutrit Soc. 2002;61(2):243–50.
30. Torheim LE, Ouattara F, Diarra MM, Thiam FD, Barikmo I, Hatløy A, Oshaug A. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. Eur J Clin Nutrit. 2004;58(4):594.
31. UNICEF (2016): The State of the World's Children 2016 Statistical Tables - UNICEF DATA. Available online at http://data.unicef.org/resources/state-worlds-children-2016-statistical-tables/, Accessed 30 July 2018.
32. Walsh CM, Dannhauser A, Joubert G. The impact of a nutrition education programme on the anthropometric nutritional status of low-income children in South Africa. Public Health Nutrit. 2002;5(1):3–9. https://doi.org/10.1079/phn2001204.
33. World Health Organization. The double burden of malnutrition. Policy brief. 2017. Accessed 15 Jan 2018.
34. World Health Organization. Obesity and overweight. 2018. http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

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