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Zoé Colombet, Pascal Leroy, Louis-Georges Soler, Caroline Méjean

Title page

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Running Title: Diet changes and diabetes risk in the Caribbean

Zoé Colombet[1]* PhD, Pascal Leroy[2] Msc, Louis-Georges Soler[2] PhD, Caroline Méjean[1] PhD

1. MOISA, Univ Montpellier, CIRAD, CIHEAM-IAMM, INRAE, Montpellier SupAgro, Montpellier, France
2. ALISS, INRAE 1303, Ivry-sur-Seine, France.

Corresponding author: Zoé Colombet

INRAE, UMR 1110 MOISA, 2 place Pierre-Viala, F-34000 Montpellier, France

Phone number: 00 33 4 99 61 30 03

E-mail: zoe.colombet@inrae.fr

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Abbreviations

BMI: body mass index

DASH: Dietary Approaches to Stop Hypertension

DQI-I: Diet Quality Index-International

mPNNS-GS: modified Programme National Nutrition Santé-Guideline Score

PNNS-GS2: Programme National Nutrition Santé-Guideline Score 2

PRIME: Preventable Risk Integrated ModEl

T2DM: type-2 diabetes mellitus

Abstract

Purpose: As the French West Indies are facing an ongoing nutrition transition with increasing type-2 diabetes mellitus (T2DM) prevalence, our study aimed to evaluate the effect of potential shifts in dietary patterns on T2DM risk in French West Indian adults according to several scenarios.

Methods: We used a cross-sectional multistage sampling survey on dietary intake conducted in 2013 on a representative sample of Guadeloupeans and Martinicans adults (n=1,063). From previously identified current dietary patterns, we used PRIME-Diabetes, a comparative risk assessment model, to estimate the effect of potential shifts from the "transitioning" pattern to the "convenient," the "prudent," and the "traditional" ones on T2DM risks.

Results: Potential shift in dietary intakes from the "transitioning" pattern to the "traditional" one reduced the T2DM risk in women (-16% [-22; -10]) and in men (-14% [-21; -7]), as the shift in dietary intakes toward the "prudent" pattern (-23% [-29; -17] and -19% [-23; -14], respectively). These risk reductions were mostly driven by increased whole grains, fruits, green leafy vegetable intakes, and decreases in potatoes, red meats, processed meats, and sugar-sweetened beverages. The shift in dietary intakes toward the "convenient" pattern did not affect the T2DM risks.

Conclusion: To curb the increase in T2DM prevalence and reduce this burden, one public health action could be to target transitioning adults and help them to shift towards a diet associated with a reduced risk of T2DM as a prudent or a traditional diet.

Keywords: French West Indies; dietary changes; PRIME; diabetes

Text

Introduction

Type-2 diabetes mellitus (T2DM) prevalence has increased rapidly in the Caribbean in the past decades becoming one of the leading causes of death (11% of total deaths) and premature disability and one of the most challenging public health issues [1–4]. Reported diabetes prevalence in the Caribbean steadily increased from 5% in the 1980s to 10% in 2014 [5, 6]. In addition, diabetes prevalence ranged from 11 to 18% in several English-speaking Caribbean countries [3]. In the French West Indies, the public National Information System for Health Insurance estimated an increase in prevalence of treated diabetes (age- and sex-standardised) from 7 to 9% between 2006 and 2015 in Guadeloupe and 7 to 8% in Martinique (4 to 5% in entire France), marking one of the largest increases in France [7, 8].

Dietary habits and sedentary lifestyles are the major factors of the rapidly rising incidence of T2DM among countries that have experienced fast nutrition transition [9, 10]. Briefly, the nutrition transition is schematically described as the transition from a traditional to a “Western” dietary pattern, generally characterised by high intakes of saturated fats, sugars, and refined foods and low intakes of fiber-rich foods, mainly owing to the high availability of cheap energy-dense, nutrient-poor foods [11]. There are few studies characterising the nutrition transition in the French West Indies. A recent study observes, over a relatively short period, changes consistent with the nutrition transition theoretical framework [12]. Another study, by the authors, highlighted four current coexisting dietary patterns reflecting different steps in dietary change as described in the nutritional transition literature [13]. These four dietary patterns were identified on the Kannari survey using a weighted principal component analysis (PCA) and a clustering procedure. First, a “traditional” pattern was identified with a high diet quality, characterized by high intakes of fruits, vegetables, tubers, fish, and traditional French West Indian dishes, and low intakes of red and processed meat, snacks, fast foods, and sweetened beverages, mostly composed by women and older persons. Two globalised patterns were identified: a "prudent" pattern with a high diet quality and a "convenient" pattern with low diet quality. The "prudent" pattern, mostly composed by Guadeloupeans and by individuals living in a couple, is characterized by high intakes of fruits, vegetables, legumes, seafood and yoghurts, and low intakes of fatty and sweet products. The "convenient" pattern is characterized by high intakes of sweetened beverages, snacks, and fast foods, and is principally composed by young. Finally, a "transitioning" pattern was identified, which includes high intakes of traditional (tubers, legumes, fish) and "convenient" foods (bread, processed meat, sauces, sweetened beverages), resulting in intermediate diet quality. Given that this "transitioning" pattern is intermediate, composed by 27% of the population, mainly middle-aged individuals, we can hypothesise that this group of the population will change their diet in the coming years. These "transitioning" individuals may continue their nutrition transition toward a more globalised, less healthy diet ("convenient" pattern) or a healthier diet ("prudent" pattern), as predicted by the nutrition transition framework [11]. Alternatively, they may change towards a "traditional" pattern with the implementation of specific food policies. Indeed, as shown in a food market characterization study, there is currently an increasing trend for food choices based on more transparency and naturalness among the French West Indians, with a strong emphasis on local products and a real awareness of the link between food and health [14]. Also, strengthening local and traditional food production is an important issue with regard to multiple dimensions (food and nutrition security, ecologic, health, economic) as evidenced by it being part of the territorial food plans currently discussed by local institutions and as emphasized by the Guadeloupean food system diagnostic [15] conducted in 2019 by the French local administration with stakeholders. Our study, therefore, assumes that the French West Indian traditional diet is a realistic option if supported by the implementation of specific food policies. Furthermore, traditional diets such as the Mediterranean, Nordic, or Japanese diets, have been largely described as protective against coronary heart diseases, cancers, diabetes, and obesity [16–18]. Promoting traditional diets and their integration into the local food system has been recently emphasized in international literature as a new avenue for more sustainable diets [18]. Thus, actions from health and nutrition policies targeting these "transitioning" individuals may be a real lever to prevent a shift to a less healthy diet.

Simulation studies such as the Preventable Risk Integrated ModEl (PRIME), assess the population-level impact of different dietary intake scenarios on nutrition-related mortality[19]. These simulations are essential for policy-makers as they provide useful estimates of the potential health-related gains from a given change [19]. PRIME-Diabetes allows us to estimate the variation in the T2DM risk related to dietary changes [20].

Using the PRIME-Diabetes model, we aimed to evaluate several scenarios to estimate the potential impact of shifts from the "transitioning" pattern toward another pattern on the T2DM risk in French West Indian adults, and to identify the foods that contribute the most to these changes of T2DM risk.

Subjects and Methods

Population

We used the cross-sectional Kannari survey conducted in 2013 in in children (≥3 years) and adults (16 to 95 years) of Martinique and Guadeloupe, two French regions. This is described in-full elsewhere [13, 21, 22]. Briefly, the Kannari survey, aimed to be representative, was based on multistage stratified random samples of the French West Indies populations to describe food intakes, health, and nutritional status. Sample selection was based on a three-stage cluster design (geographic areas, household, and individuals in the household), stratified by chlordecone contamination areas (coastline and inland). Among the 2,514 households initially selected in Guadeloupe and 2,548 in Martinique, 1,671 and 1,616 were respectively included after excluding the ineligible or not reachable households (**Supplemental Figure 2**). To be eligible, the household needed to be resident in the French West Indies for at least six months, to continue residing in the French West Indies during the three months following first contact, and the individuals needed to reside in the household at least four days a week and able to complete the survey. Of the contacted and eligible households, 880 participated in Guadeloupe and 919 in Martinique [21]. The household participation rate was thus 52.7% in Guadeloupe and 56.9% in Martinique. Among the participating households, 668 adults in Guadeloupe and 673 in Martinique responded to at least one 24-hour recall, representing individual participation rates of 75.9 % and 73.2%, respectively. For the present analysis, we only used adults aged 25 years old or over as it was the minimum age available from the adult population data used (i.e., 25-34 years old was the first bracket to be totally adult, the previous one being 15-24 years old).

The Kannari survey respected the Declaration of Helsinki guidelines and received approval from the French Data Protection Authority (N°05-1170) and an ethical research committee (CPP N°2-13-10). Written informed consent was obtained from all participants.

Data collection

Questionnaires collecting demographic and socioeconomic characteristics and health status were administered at home through face-to-face interviews. Anthropometric data were measured by trained interviewers with both French and Creole language skills. For this analysis, socioeconomic indicators were education, employment status, and being a recipient or not of social assistance benefits. Demographic characteristics were sex, age, location (Guadeloupe or Martinique), single-parent household, presence or not of at least one child in the household. We also used the weight and the height, both measured at participants' homes. Body mass index

(BMI) was calculated and categorized according to the World Health Organization (WHO) classification [23] and recoded into three categories: underweight (BMI<18.5) or normal weight (18.5≤BMI<25.0), overweight and obese (BMI≥25.0).

Dietary data were collected by phone using two non-consecutive randomly assigned 24-hour recalls conducted by trained dieticians. Participants were asked to describe detailed dietary intake and quantities consumed during the 24 hours preceding the interview. Portion sizes were estimated using standard measurements (e.g. home containers, grams indicated on the package) or a validated illustrated booklet [24], representing more than 250 foods specific to the French West Indies (corresponding to 1000 generic foods) served in seven different portion sizes. Values for energy, macronutrients and micronutrients were estimated using published nutrient databases [25] and were extended for French West Indian market foods and recipes. In addition to the 24-hour recalls, participants completed a food frequency questionnaire (FFQ) during face-to-face interviews about their usual frequency of consumption of 119 food and beverage groups over the 12 last months. Then, we used the Multiple Source Method [26] to estimate usual dietary intake using the amounts of consumption from 24-h recalls combined with consumption frequencies from the FFQ, as described elsewhere [13, 22].

We identified and excluded energy under-reporters using the method proposed by Black [27]. However, unlike Black, we used Mifflin equations [28] to estimate the basal metabolic rate (BMR) since a high prevalence of overweight and obesity was observed in our study sample. BMR was compared to energy intake, taking into account a physical activity level of 1.55 as recommended by Black [27], the WHO value for ‘light’ activity. Subjects who reported specific conditions that could objectively explain low energy intake, such as a low-energy diet to lose weight or acute disease, were not recorded as underreporters.

The dietary intake estimations used specific survey procedures to consider weighting and stratification to consider the complex survey design (i.e., procsurveymean in the SAS software) and to be representative of the French West Indian populations [13].

Dietary patterns

The four dietary patterns used in the present analysis were identified and detailed in a previous study on the Kannari survey, led by our team [13]. The dietary patterns in the French West Indian population were identified using a two-step method: a principal component analysis (PCA) on food group intakes followed by a clustering procedure, as detailed elsewhere [29, 30]. The PCA was used as a dimension-reduction technique to reduce the initial range of information by maximising variance. Next, the clustering procedure using the dimensions retained in the PCA enables the grouping of the participants into homogeneous, non-overlapping groups based on their similarities in a particular set of variables [29]. In this analysis, clustering results in grouped subjects in a similar pattern of mean food intake. Thus, each cluster can then be qualified as a dietary pattern.

We first applied a weighted PCA on food group intakes (in grams per day) adjusted for daily energy intake according to sex [13]. We used the residual method to adjust for daily energy intake, which allows us to estimate differences in intakes not driven by differences in energy intake. To be representative of the French West Indian population, the PCA was weighted using the Kannari survey weights calculated for each sex on age, education, marital status, birthplace, presence of at least one child in the household, living in an area with chlordecone contamination (coastline and inland) and urban size as previously described [13]. Food groups with a factor loading coefficient under 0.25 were excluded. The PCA was applied to the 25 food group intakes among 39 available (Fruits; Vegetables; Bread and rusk; Potato; Tubers (other than potatoes); Pasta; Rice; Semolina and other cereals; Legume; Whole-grain products; Fishs;

Seafoods; Red meats; Poultry; Processed meats; Offal; Yogurts; Salad dressing and sauces; Butter; Snacks and fast foods; Biscuits, cakes and pastries; Fatty and sweet products (e.g., chocolate, ice cream); Non-alcoholic and non-sweetened beverages (e.g., water, coffee, tea); Sweetened beverages and juices; and Alcoholic beverages).

PCA generates independent linear combinations of the initial food group variables, maximizing the explained variance. Factors were rotated by an orthogonal transformation. According to eigenvalues above 1.5, Scree test (Cattell test) and interpretability of factors, three dimensions were retained [13].

Next, we performed a clustering procedure on these three dimensions using Ward's hierarchical classification of the individuals, maximizing the inter-class inertia. The graphical observation of the dendrogram, illustrating stages of classification, pseudo-F, pseudo-t2, and the cubic clustering criterion (CCC) was used to estimate the appropriate number of clusters [13]. After cluster stabilization was carried out to distribute the individuals better by clusters, we evaluated the robustness of the classification using kappa coefficients, markers of agreement between each simulated sample, and the whole sample, calculated for 50 randomly selected samples composed of three-quarters of the whole sample, using an equal probability sampling method [13].

This cluster analysis yielded groups interpreted as dietary patterns and labelled according to their main food intakes.

<u>Statistical analysis</u>

Estimating the risk of Type-2 Diabetes

We evaluated the potential impact of dietary pattern substitution on the T2DM risk using a model structurally similar to the Preventable Risk Integrated ModEl (PRIME) [19] as developed by Adjibade *et al.* [20]. PRIME is a comparative risk assessment model designed to estimate the impact of changes in the age- and sex-specific distribution of one or more of twelve behavioural risk factors of non-communicable diseases mortality. This risk factors were direct associations or mediating factors that include body mass index (BMI), blood pressure and blood cholesterol [19]. Briefly, PRIME estimates the change in the annual number of deaths between the baseline and counterfactual scenarios that depends on changes in the distribution of behavioural risk factors in the study population. Based on the same principle Adjibade *et al.* developed PRIME-Diabetes, a model estimating the variation in T2DM risk related to lifestyle changes [20]. As originally reported [19], risk relationships were drawn from published meta-analyses and included parameters appropriately adjusted for other behavioural risk factors to minimize the risk of double-counting of effect size.

PRIME-Diabetes was set up using relative risk data on the dose-response associations between the T2DM risk and each food group or nutrient identified as having an impact on the risk of T2DM: whole grains, refined grains, fruits, green leafy vegetables, other vegetables, nuts, potatoes, dairy products, red meats, processed meats, butter, fish, eggs, olive oil, tea, coffee, chocolate, sugar-sweetened beverages, daily energy, carbohydrates, magnesium [20] (**Supplementary Figure 1)**. Additionally, change in energy intake is an important factor for T2DM risk estimates as energy imbalance is associated with being overweight, itself associated with the T2DM risk [20]. Thus, the model was parameterized so that a change in energy intake resulted in a change in the T2DM risk as a function of the BMI and the level of physical activity of the participants [20]. As the information on physical activity was not available for our study, an average level of physical activity was defined making it constant. Also, we did not include alcohol intake in our analyses as alcohol intake is highly under-reported in our sample.

To summarise, within PRIME-Diabetes, diet can impact T2DM risk through two distinct pathways as shown in **Supplementary Figure 1:** (1) through food group and nutrients intakes directly, independently of the energy intake, (referred as dietary effect), and (2) through energy intake and BMI.

Dietary patterns substitution scenarios

Based on the four coexisting dietary patterns previously identified (prudent, traditional, convenient and transitioning) [13], we have evaluated the changes in the T2DM risks for three counterfactual scenarios. The “transitioning” pattern was considered as the baseline situation as it was characterised by both high intakes of traditional and “modern” foods, resulting in intermediate diet quality. Furthermore, the “transitioning” pattern was mainly composed by middle-aged individuals. We hypothesised that the “transitioning” pattern group may shift towards a traditional diet or may, by continuing the nutrition transition, shift toward a more globalised diet. Thus, we estimated changes in the T2DM risks replacing the “transitioning” pattern by another pattern. We ask what if the “transitioning” group shifted instead towards (i) the “traditional” pattern; (ii) the “prudent” pattern; or (iii) the “convenient” pattern. The food group consumption and nutrient intakes were the means for each dietary pattern of each food group and nutrient included in PRIME-Diabetes. Note that our analyses are only based on the food intakes of the patterns; this means that the change in risk of diabetes is only due to the change in dietary intake, based on initial intakes of each dietary pattern, independently of individual characteristics.

Changes in the T2DM risk were expressed as percentages. Monte Carlo simulations (100,000 iterations) were performed to estimate 95% uncertainty intervals around the results. Given that age was highly associated with the dietary patterns and BMI is strongly associated with the

T2DM risk, the dietary intake estimations added into the PRIME-Diabetes were adjusted for age and BMI.

The PRIME model algorithm was implemented in R. All other data management and statistical analyses were conducted using SAS (version 9.4; SAS Institute Inc., Cary, NC, USA).

Results

Among the 1,799 adults (≥16 years) enrolled in the Kannari survey, 1,341 had at least one 24-hour dietary recall (**Supplemental Figure 2**). We excluded 96 adults aged under 25 and 182 energy under-reporters, leaving 1,063 participants included in the analyses.

The participants were categorized according to their dietary patterns into “transitioning”, “traditional”, “prudent”, and “convenient” patterns, representing respectively, 27, 27, 24, and 22% of the sample. **Supplementary Table 1** details the daily intake of nutritional components included in the PRIME-Diabetes model of each dietary pattern. **Supplementary Table 2** describes the demographic and socioeconomic characteristics associated with these patterns.

Table 1 describes the modelled changes in T2DM risk if subjects shifted from one pattern to another and the **Figures 1, 2** and **3** show the contribution of each nutritional component included in the PRIME-Diabetes model to these changes in T2DM risk.

<u>From the “transitioning” to the “traditional” pattern</u>

The shift from the “transitioning” pattern to “traditional” decreased the T2DM risk significantly both by changes in dietary intake and a decrease of the mean BMI due to a decrease in energy intake, mainly in women (**Table 1**). The change in dietary intake is estimated to result in the highest change in the T2DM risk: -16.0 [-22.0; -9.6] in women and -14.2 [-20.7; -7.0] in men (**Table 1**). In particular, the increase in consumption of whole grains, fruits, green leafy vegetables, olive oil (only in women), tea, and magnesium (only in men) and the decrease in consumption of potatoes, red meat, processed meats, sweetened beverages, mainly contribute to the estimated decrease in the T2DM risk whereas the decrease in the intake of coffee, butter, and magnesium (only in women) increased the T2DM risk (**Figure 1**).

From the "transitioning" to the "prudent" pattern

The shift from the "transitioning" pattern to "prudent" decreased the T2DM risk due to changes in dietary intake, and more widely for women (-23.0 [-28.7; -16.9]) than for men (-19.0 [-23.3; -14.4]), but not through a significant change in the BMI due to shifting in energy intake (**Table 1**). The increase in the consumption of whole grains, fruits, green leafy vegetables, olive oil (only in women), tea, and magnesium, and the decrease in consumption of potatoes, red meat (only in men), processed meats, and sweetened beverages contributed to reducing the T2DM risk whereas the decrease in the intake of coffee, butter, and olive oil (only in men) increased the T2DM risk (**Figure 2**).

From the "transitioning" to the "convenient" pattern

The shift from the "transitioning" pattern to "convenient" increased the T2DM risk in men through the effect of energy intake on T2DM risk through the BMI (3.4 [2.5; 4.3]): the slight increase in the energy intake increased the mean BMI. While the overall food intake changes from the "transitioning" to the "convenient" pattern did not significantly change the T2DM risk, some dietary changes have impacted the T2DM risk opposingly (**Figure 3**). Indeed, the estimated decrease in the intakes of fruits, vegetables (except green leafy ones), coffee, butter, and magnesium and the estimated increase of sweetened beverages intakes (only in men) increase the T2DM risk. On the contrary, the estimated increase in consumption of whole grains, tea, green leafy vegetables (only in women), and olive oil (only in women) and the decrease in consumption of potatoes, red and processed meats, and sweetened beverages (only in women) reduced the T2DM risk.

Discussion

The present study found that shifting from the “transitioning” pattern to a “prudent” pattern was the changing scenario that could reduce the most T2DM risks, especially among women. To a lesser extent, shifting to a “traditional” pattern could also reduce T2DM risks. The reduction in T2DM risk was specifically driven by increases in consumption of whole grains, fruits, and green leafy vegetables, and decreases in consumption of potatoes, red meats, processed meats, and sugar-sweetened beverages. Unexpectedly, shifting toward the “convenient” pattern did not change the T2DM risks. Indeed, the increase in T2DM risk due to the decrease in the intake of fruits, vegetables (except green leafy ones), coffee, butter, and magnesium was counterbalanced by the increase in consumption of whole grains, tea, green leafy vegetables (only in women) and olive oil (only in women) and the decrease in consumption of potatoes, red meats, and processed meats.

In this study, the effect of energy intake on T2DM risk through the BMI was significant in participants shifting from the “transitioning” pattern to a “traditional” one, particularly in women. This means that a decrease in energy intake decreased the T2DM risk through a decreased BMI. Also, the effect of energy intake on T2DM risk through the BMI was significant in men shifting to a “convenient” pattern, with an estimated increase in the energy intake increasing the T2DM risk through an increased BMI. In each one, the effect of energy intake on T2DM risk through the BMI had the same effect on T2DM risk that the changes in dietary intakes.

Regarding the changes in T2DM risk related to changes in dietary intakes, shifting from the "transitioning" pattern to the "prudent" or "traditional" pattern reduced the T2DM risks. This is in line with literature showing the protective effect of diets with high consumption of fruits, vegetables, legumes, whole grains, nuts, and fish, and low consumption of red and processed meats, refined grains, and sugar-sweetened beverages [31–33]. Our analyses however underline that a shift from the "transitioning" pattern to a "traditional" one did not reduce the T2DM risk as much as a shift toward a "prudent" pattern, especially among women. Yet, previous analyses had shown that the "traditional" pattern had higher overall dietary quality scores (evaluated using the Diet Quality Index-International (DQI-I) and the modified Programme National Nutrition Santé-Guideline Score (mPNNS-GS)) than the "prudent" one (65.4 *vs.* 64.0 points and 9.0 *vs.* 8.6 points, respectively) [13]. In addition, shifting from the "transitioning" pattern to the "convenient" pattern did not significantly change the T2DM risk whereas the diet quality score of the "convenient" pattern was much lower than the score of the "transitioning" one (54.6 *vs.* 60.8 points and 7.6 *vs.* 8.1 points, respectively). In the literature, dietary indexes reflecting the overall healthiness of the diet were associated with a reduction in T2DM incidence even if the quality of evidence was generally low [32, 34–36]. For example, participants with high versus low Programme National Nutrition Santé-Guideline Score 2 (PNNS-GS2), Mediterranean dietary score, and DASH score had a reduction of 49%, 15% and 20% in their T2DM risk, respectively [34, 36]. These results suggest a role of the quality of dietary patterns as a whole rather than specific components, supporting the idea that as foods interact with each other as part of the diet, it is important to capture the synergic effects caused by the dietary matrix [34]. Yet, in our study, it appears that overall dietary quality scores mask finer dietary characteristics that strongly impact T2DM risk. Indeed, this higher decrease in T2DM risk for shifting to "prudent" rather than toward the "traditional" one can be explained by the higher changes in intakes of whole grains, vegetables, processed meats (in women), sugar-sweetened beverages, and tea. Also, specific food intake in "prudent" and "traditional" patterns increased the T2DM risk despite high overall diet quality scores for these patterns. In contrast, shifting from the "transitioning" to the "convenient" pattern did not significantly change the overall T2DM risk. Indeed, the changes in intakes of foods increasing the T2DM risk (i.e., fruits, sugar-sweetened beverages (in men), coffee, butter, and magnesium) was counterbalanced by changes in intakes in foods that allow decreased T2DM risk (i.e., whole grain products, green leafy, potatoes, red meat, processed meat, and tea). Note that more pronounced results in women may be due to the wider changes in the intakes.

Our results support the idea that the nutrition transition is advanced in the French West Indies [13] as the "transitioning" pattern group has a diet similar to the diet of the "convenient" pattern group except for higher intake of fruits and vegetables which has a small effect on the T2DM risk (relative risk in PRIME-Diabetes of 0.98 for fruits, 0.87 for green leafy vegetables, and 0.98 for other vegetables), but have a significant weight on overall dietary quality scores. In the light of our results, our study emphasizes the limitation of overall diet quality scores to predict T2DM risk in concordance with previous reviews showing that diet quality scores are often modestly associated with mortality or disease risk, and do not predict morbidity or mortality significantly better than individual dietary factors [37]. This emphasises the need for specific recommendations in these populations, beyond global recommendations.

Among the foods involved in the T2DM risk identified in the literature, our study has identified key food groups based on the French West Indian diet, offering levers to prevent diabetes in these islands. Looking at the shift from the "transitioning" pattern to the "prudent" or "traditional" ones, the same foods are involved in the change in T2DM risk, but in different orders. Shift to the "prudent" pattern was stronger because the changes in food intakes are wider than the changes for the shift to the "traditional" pattern. Moreover, the Caribbean traditional foods are not highly diabetes protective. For instance, fish is not a central element in reducing the T2DM risk, and traditional tubers are not even included in the model even if they have many potential beneficial effects on diabetes in mice [38–40]. However, as the change in dietary intake from the "transitioning" to the "traditional" diet is smaller than to the "prudent" one, it seems to be more feasible. And as it still leads to a high reduction in T2D risk, promotion of a "traditional" diet seems to be the best possible compromise. Especially as the “traditional” diet is more culturally acceptable, and as it is made up of local foods, it could be more economically accessible, therefore easier to promote and implement for the population.

The key food group associated with a reduction of the T2DM risk is whole grain products for which the increasing intake was associated with the larger effects. The protective effect of the whole grain product consumption against T2DM may be partly explained through reduced fasting glucose and insulin concentrations, reduced adiposity, lower concentrations of inflammatory markers (e.g. C reactive protein) and high content of several nutrients, vitamins, minerals, and phytochemicals for example [31, 36]. Similarly, the potential mechanistic explaining the protective effect of fruits and vegetables on the T2DM risk is mainly based on their fiber content, which has been shown to improve insulin sensitivity and secretion to overcome insulin resistance [31]. Another possible explanation is that vegetable and fruit intake indirectly influence T2DM risk by preventing weight gain and adiposity risk [31].

Our study underlines that reduction of processed meat intakes offers one of the most important strategies to reduce the T2DM risk. Indeed, processed meat intakes are positively associated with higher fasting glucose and insulin concentrations, and high amounts of sodium, haem iron, nitrates, nitrites for example [31, 36]. Another lever to reduce the T2DM risk in the French West Indies is to decline the consumption of sugar-sweetened beverages. Indeed, sugar-sweetened beverages have a high glycaemic index and their consumption is associated with increased blood glucose concentration [31, 36]. Also, fructose in sugar-sweetened beverages promotes hepatic lipogenesis and insulin resistance and sugar-containing liquids negatively affect the regulation of hunger and satiety [31, 36].

Finally, our paper supports the recommendations that promoted the consumption of whole grain products, fruits, and green leafy vegetables to reduce the T2DM incidence and prevalence in the French West Indies. But in these islands, food is expensive, and a large part of the population is disadvantaged, so we need to combine action to increase these intakes. However, as previously underline in literature [31], reducing the consumption of risk-increasing foods seems to have more impact on T2DM risk than increasing risk-reducing foods. Yet, consumption of processed meat and sugar-sweetened beverages are markers of the nutritional transition that is still ongoing in the French West Indies, implying that these consumptions will increase thus leading to higher T2DM risk. Policies aiming at limiting these increases or even reducing these consumptions need to be implemented. However, as individuals reducing their consumption of risk-increasing foods are likely to replace it to some extent with something else, promoting risk-reducing foods is still important. Thus, promoting the “traditional” diet seems to be a good compromise, especially as it is culturally acceptable and economically accessible, and as a trend of purchasing local products occurs in the French West Indies [14]. In addition, beyond the positive impacts on the health of the population, it will also have a positive impact on the local food system as it favours the local economy as previously underline [15].

The interpretation of our results presents some limitations. First, a major limitation is that PRIME-Diabetes was parametrized with available relative risks from meta-analyses, mostly estimated for the general population independently of socioeconomic distribution in the population, while for some parameters, the actual risks may vary as a function of socio-demographic and health characteristics. The PRIME model does not allow to adjust a posteriori for sociodemographic and economic characteristics that leads to estimate relative risks without accounting for important potential confounders. Additionally, in the absence of reliable information, we considered that the initial T2DM risk was the same for all the population subgroups examined in our study. In the French West Indian populations, mainly composed of African descendants and particularly marked by social inequalities, it is highly likely that the relative risks are different from those included in the original model. Also, in the Caribbean populations, women have statistically higher risks of T2DM than men [6, 41–43], unlike in mainland France and most northern countries. In addition, some nutritional factors were not included in the PRIME-Diabetes, either because they have not been sufficiently documented or due to a lack of detailed data on their contents in different foods [20]. Also, as most of the foods marker of the traditional diet was not included in the PRIME-Diabetes, the model is not admirably adapted to the Caribbean diet where potatoes are not widely consumed, unlike traditional tubers. In the present analyses, alcohol intake, and physical activity level were not included in the models although they are important risk factors. We decided not to consider alcohol consumption as it’s highly misreported in our sample and as we know from descriptive analysis that the “transitioning” pattern has the highest alcohol consumption. Thus, we can imagine that considering alcohol consumption in our model will have biases the results by showing unrealistic decreases in diabetes risks due to large decreases in alcohol consumption. Also, given that a large part of the population of the French West Indies belonged to low socioeconomic classes, the household participation rate from the Kannari survey was around 50% which may lead to a selection bias. However, the use of weights should have attenuated this limit. Finally, the dietary patterns used in our analysis are based on the latest data available for the French West Indies (Kannari survey from 2013). They may not therefore reflect current intakes.

Conclusion

Despite the role of ageing and other non-modifiable risk factors in morbidity and mortality from diabetes, changes in diet have a strong impact on the T2DM risk. Shifting to a "prudent" diet will widely reduce the T2DM risk in the French West Indian populations, as a shift to a "traditional" diet to a lesser extent, due to increased consumption of fruits, green leafy vegetables, and mostly whole grain products, and most importantly the reduced consumption of processed meat and sugar-sweetened beverages. Therefore, to stop the increase in T2DM prevalence and reduce this burden in these populations, one lever could be to help adults to change their diet toward a “prudent” or a “traditional” diet by promoting them.

Declarations

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Conflict of interest: The authors declare that they have no conflict of interest.

Availability of data and material: Data described in the manuscript, codebook, and analytic code cannot be made available because they were provided by the French public health agency (Santé Publique France) and are not accessible to the public. Requests can be made to the French public health agency.

Authors' contributions: The authors' responsibilities were as follows: CM and LGS designed the study, ZC drafted the manuscript, ZC performed the statistical analysis, PL performed the PRIME-Diabetes model, PL, CM and LGS contributed to the data interpretation and revised each draft for important intellectual content. All authors read and approved the final manuscript.

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Table 1. Modelled changes on the risk of Type-2 Diabetes (percentage) if Guadeloupean and Martinican adults (≥25 years) from the "transitioning" pattern shifted to another pattern ("traditional", "prudent" or "convenient), Kannari study (n = 1,063).

	Transitioning to Traditional		**Transitioning to Prudent**		**Transitioning to Convenient**	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Effect of energy intake through the BMI	**-14.1 [-23.3 ; -3.0]**	**-0.8 [-1.1 ; -0.5]**	-13.2 [-24.3 ; 0.7]	-6.1 [-13.6 ; 2.4]	-15.1 [-49.0 ; 43.3]	**3.4 [2.5 ; 4.3]**
Dietary effect	**-16.0 [-22.0 ; -9.6]**	**-14.2 [-20.7 ; -7.0]**	**-23.0 [-28.7 ; -16.9]**	**-19.0 [-23.3 ; -14.4]**	-1.5 [-10.6 ; 8.3]	2.5 [-4.1 ; 9.4]

Abbreviation: BMI: Body Mass Index

Values are presented as percentage (%) and [95% uncertain interval].

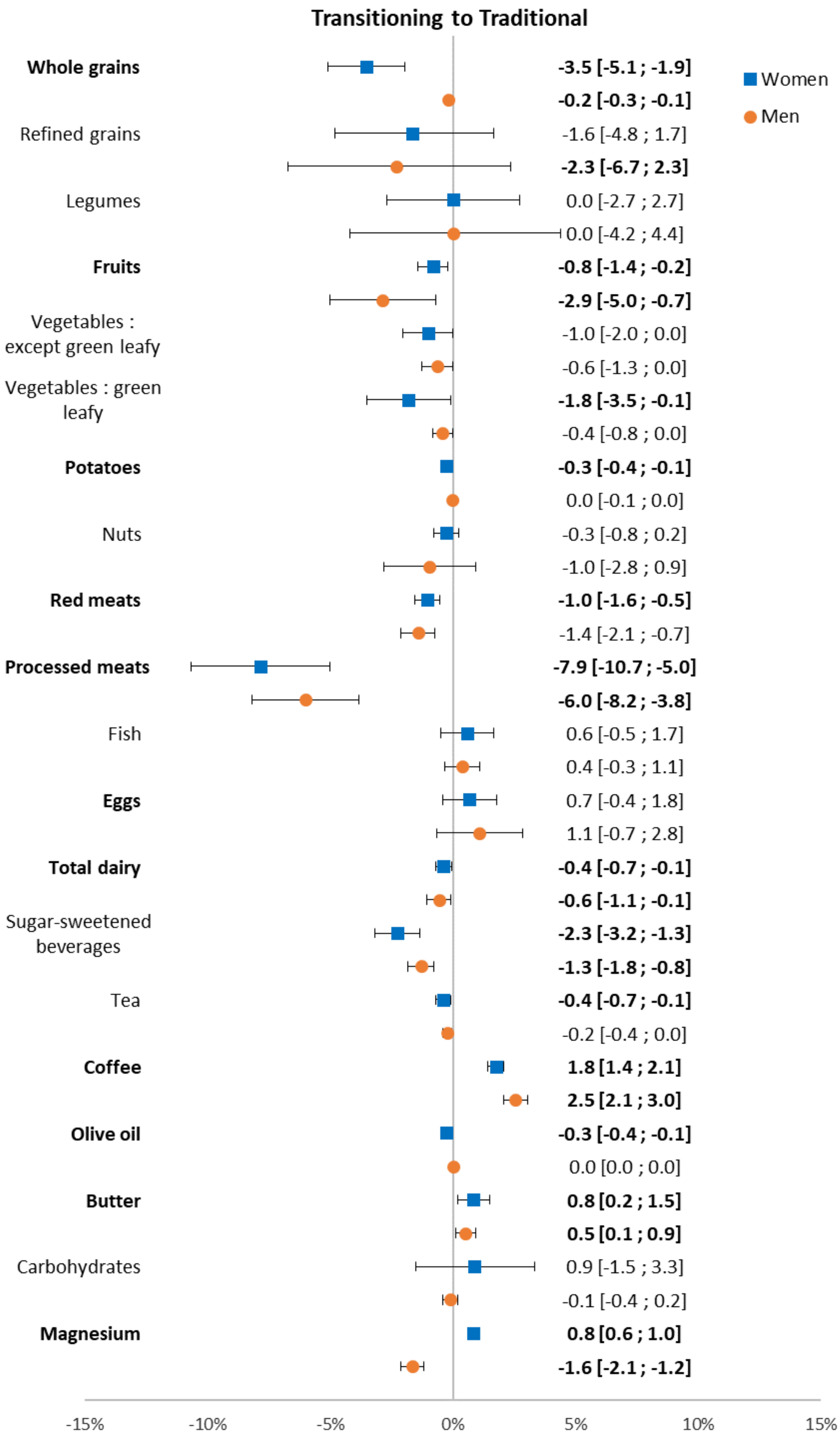
Transitioning to Traditional
Women
Men
Whole grains
-3.5 [-5.1 ; -1.9]
-0.2 [-0.3 ; -0.1]
Refined grains
-1.6 [-4.8 ; 1.7]
-2.3 [-6.7 ; 2.3]
Legumes
0.0 [-2.7 ; 2.7]
0.0 [-4.2 ; 4.4]
Fruits
-0.8 [-1.4 ; -0.2]
-2.9 [-5.0 ; -0.7]
Vegetables : except green leafy
-1.0 [-2.0 ; 0.0]
-0.6 [-1.3 ; 0.0]
Vegetables : green leafy
-1.8 [-3.5 ; -0.1]
-0.4 [-0.8 ; 0.0]
Potatoes
-0.3 [-0.4 ; -0.1]
0.0 [-0.1 ; 0.0]
Nuts
-0.3 [-0.8 ; 0.2]
-1.0 [-2.8 ; 0.9]
Red meats
-1.0 [-1.6 ; -0.5]
-1.4 [-2.1 ; -0.7]
Processed meats
-7.9 [-10.7 ; -5.0]
-6.0 [-8.2 ; -3.8]
Fish
0.6 [-0.5 ; 1.7]
0.4 [-0.3 ; 1.1]
Eggs
0.7 [-0.4 ; 1.8]
1.1 [-0.7 ; 2.8]
Total dairy
-0.4 [-0.7 ; -0.1]
-0.6 [-1.1 ; -0.1]
Sugar-sweetened beverages
-2.3 [-3.2 ; -1.3]
-1.3 [-1.8 ; -0.8]
Tea
-0.4 [-0.7 ; -0.1]
-0.2 [-0.4 ; 0.0]
Coffee
1.8 [1.4 ; 2.1]
2.5 [2.1 ; 3.0]
Olive oil
-0.3 [-0.4 ; -0.1]
0.0 [0.0 ; 0.0]
Butter
0.8 [0.2 ; 1.5]
0.5 [0.1 ; 0.9]
Carbohydrates
0.9 [-1.5 ; 3.3]
-0.1 [-0.4 ; 0.2]
Magnesium
0.8 [0.6 ; 1.0]
-1.6 [-2.1 ; -1.2]
-15%
-10%
-5%
0%
5%
10%
15%

Figure 1. Modelled impact of dietary changes on the risk of Type-2 Diabetes (percentage) if Guadeloupean and Martinican adults (≥25 years) from the "transitioning" pattern shifted to the "traditional" pattern, Kannari study (*n* = 1,063).

Values are presented as percentage (%) and [95% uncertain interval].

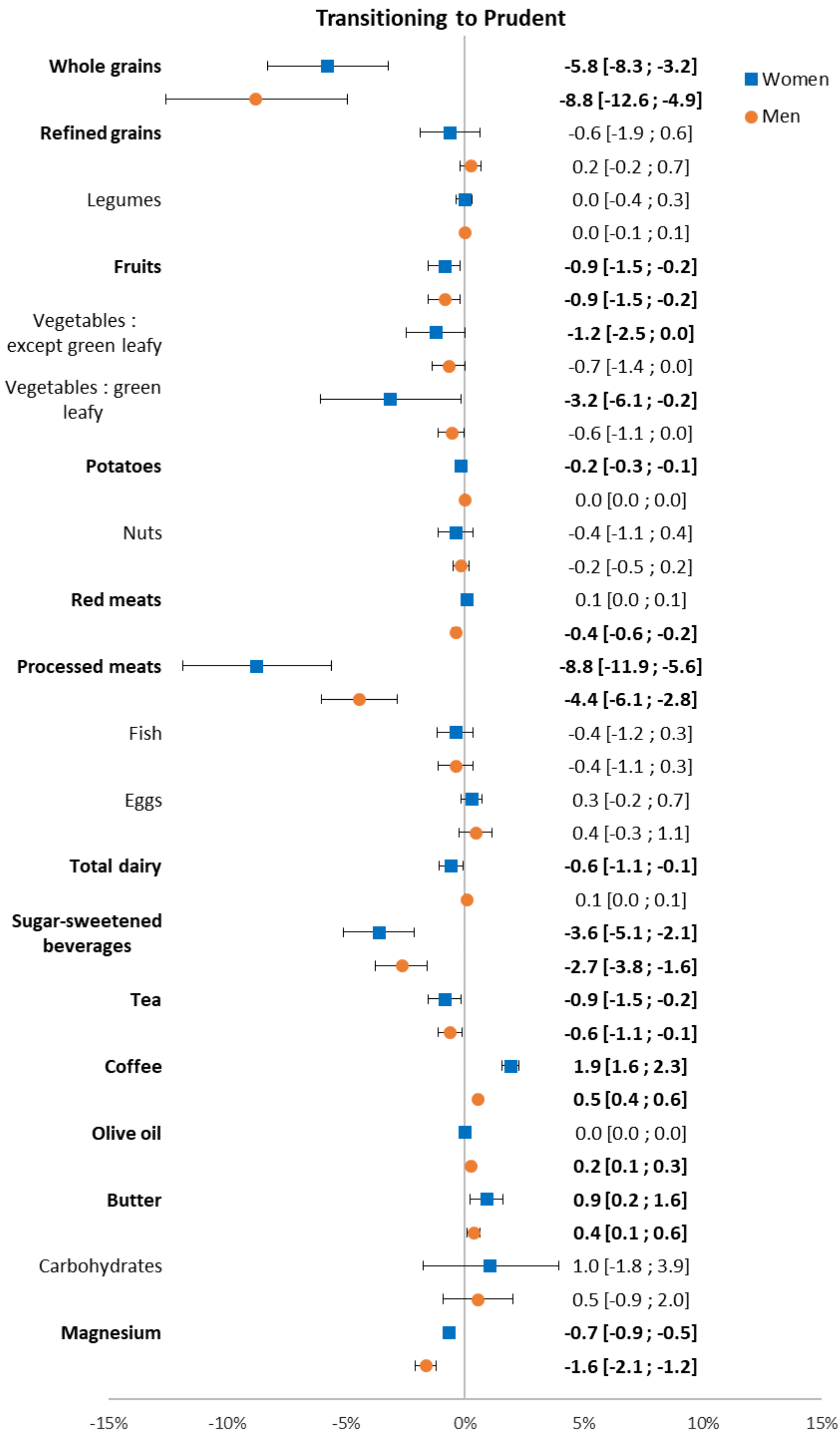
Transitioning to Prudent
Women
Men
Whole grains
-5.8 [-8.3 ; -3.2]
-8.8 [-12.6 ; -4.9]
Refined grains
-0.6 [-1.9 ; 0.6]
0.2 [-0.2 ; 0.7]
Legumes
0.0 [-0.4 ; 0.3]
0.0 [-0.1 ; 0.1]
Fruits
-0.9 [-1.5 ; -0.2]
-0.9 [-1.5 ; -0.2]
Vegetables : except green leafy
-1.2 [-2.5 ; 0.0]
-0.7 [-1.4 ; 0.0]
Vegetables : green leafy
-3.2 [-6.1 ; -0.2]
-0.6 [-1.1 ; 0.0]
Potatoes
-0.2 [-0.3 ; -0.1]
0.0 [0.0 ; 0.0]
Nuts
-0.4 [-1.1 ; 0.4]
-0.2 [-0.5 ; 0.2]
Red meats
0.1 [0.0 ; 0.1]
-0.4 [-0.6 ; -0.2]
Processed meats
-8.8 [-11.9 ; -5.6]
-4.4 [-6.1 ; -2.8]
Fish
-0.4 [-1.2 ; 0.3]
-0.4 [-1.1 ; 0.3]
Eggs
0.3 [-0.2 ; 0.7]
0.4 [-0.3 ; 1.1]
Total dairy
-0.6 [-1.1 ; -0.1]
0.1 [0.0 ; 0.1]
Sugar-sweetened beverages
-3.6 [-5.1 ; -2.1]
-2.7 [-3.8 ; -1.6]
Tea
-0.9 [-1.5 ; -0.2]
-0.6 [-1.1 ; -0.1]
Coffee
1.9 [1.6 ; 2.3]
0.5 [0.4 ; 0.6]
Olive oil
0.0 [0.0 ; 0.0]
0.2 [0.1 ; 0.3]
Butter
0.9 [0.2 ; 1.6]
0.4 [0.1 ; 0.6]
Carbohydrates
1.0 [-1.8 ; 3.9]
0.5 [-0.9 ; 2.0]
Magnesium
-0.7 [-0.9 ; -0.5]
-1.6 [-2.1 ; -1.2]
-15%
-10%
-5%
0%
5%
10%
15%

Figure 2. Modelled impact of dietary changes on the risk of Type-2 Diabetes (percentage) if Guadeloupean and Martinican adults (≥25 years) from the "transitioning" pattern shifted to the "prudent" pattern, Kannari study (*n* = 1,063).

Values are presented as percentage (%) and [95% uncertain interval].

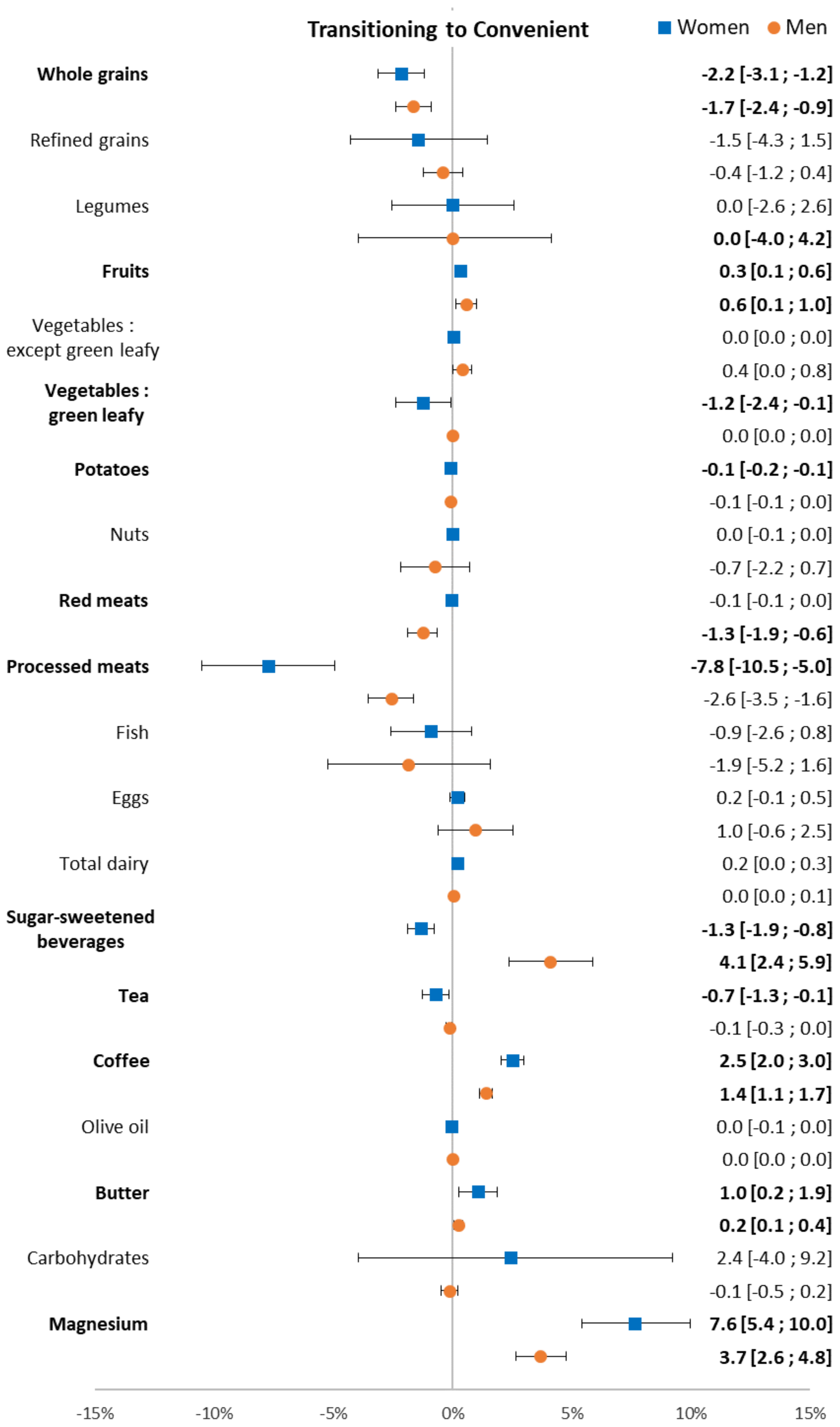
Transitioning to Convenient
Women
Men
Whole grains
-2.2 [-3.1 ; -1.2]
-1.7 [-2.4 ; -0.9]
Refined grains
-1.5 [-4.3 ; 1.5]
-0.4 [-1.2 ; 0.4]
Legumes
0.0 [-2.6 ; 2.6]
0.0 [-4.0 ; 4.2]
Fruits
0.3 [0.1 ; 0.6]
0.6 [0.1 ; 1.0]
Vegetables : except green leafy
0.0 [0.0 ; 0.0]
0.4 [0.0 ; 0.8]
Vegetables : green leafy
-1.2 [-2.4 ; -0.1]
0.0 [0.0 ; 0.0]
Potatoes
-0.1 [-0.2 ; -0.1]
-0.1 [-0.1 ; 0.0]
Nuts
0.0 [-0.1 ; 0.0]
-0.7 [-2.2 ; 0.7]
Red meats
-0.1 [-0.1 ; 0.0]
-1.3 [-1.9 ; -0.6]
Processed meats
-7.8 [-10.5 ; -5.0]
-2.6 [-3.5 ; -1.6]
Fish
-0.9 [-2.6 ; 0.8]
-1.9 [-5.2 ; 1.6]
Eggs
0.2 [-0.1 ; 0.5]
1.0 [-0.6 ; 2.5]
Total dairy
0.2 [0.0 ; 0.3]
0.0 [0.0 ; 0.1]
Sugar-sweetened beverages
-1.3 [-1.9 ; -0.8]
4.1 [2.4 ; 5.9]
Tea
-0.7 [-1.3 ; -0.1]
-0.1 [-0.3 ; 0.0]
Coffee
2.5 [2.0 ; 3.0]
1.4 [1.1 ; 1.7]
Olive oil
0.0 [-0.1 ; 0.0]
0.0 [0.0 ; 0.0]
Butter
1.0 [0.2 ; 1.9]
0.2 [0.1 ; 0.4]
Carbohydrates
2.4 [-4.0 ; 9.2]
-0.1 [-0.5 ; 0.2]
Magnesium
7.6 [5.4 ; 10.0]
3.7 [2.6 ; 4.8]
-15%
-10%
-5%
0%
5%
10%
15%

Figure 3. Modelled impact of dietary changes on the risk of Type-2 Diabetes (percentage) if Guadeloupean and Martinican adults (≥25 years) from the "transitioning" pattern shifted to the "convenient" pattern, Kannari study (*n* = 1,063).

Values are presented as percentage (%) and [95% uncertain interval].