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Abbreviations

95% CI: 95% confidence interval

BMI: body mass index

BMR: basal metabolic rate

DQI-I: Diet Quality Index-International

FFQ: food frequency questionnaire

HDL: High-Density Lipoprotein

MetS: metabolic syndrome

NRF: Nutrient-Rich Foods Index

OR: Odds ratio

PCA: Principal component analysis

SE: Standard error

SEM: Standard error of mean

SES: Socioeconomic status

Abstract

Purpose: Despite the urgency regarding increasing rates of obesity and chronic diseases in the Caribbean, few studies described the nutrition transition. We aimed to provide such information by identifying dietary patterns in the French West Indies and their characteristics.

Methods: This cross-sectional analysis included 1,144 Guadeloupeans and Martinicans from a multistage sampling survey conducted on a representative sample. Dietary patterns were identified using principal component analysis followed by a clustering procedure, and described using multivariable regression models.

Results: Four patterns were identified: (i) a "prudent" pattern characterized by high intakes of fruits, vegetables, legumes, seafood and yogurts, low intakes of fatty and sweet products, and a high Diet Quality Index-International (DQI-I); (ii) a "traditional" pattern characterized by high intakes of fruits, vegetables, tubers and fish, low intakes of red and processed meat, snacks, fast foods, and sweetened beverages, with a high DQI-I, mostly shaped by women and older persons; (iii) a "convenient" pattern characterized by high intakes of sweetened beverages, snacks, and fast foods, with the lowest DQI-I, principally shaped by young participants; (iv) a "transitioning" pattern characterized by high consumptions of bread, processed meat, sauces, alcoholic and sweetened beverages, but also high intakes of tubers, legumes, and fish, mainly shaped by men, middle aged, of whom 35% had metabolic syndrome.

Conclusion: The co-existing dietary patterns in the French West Indies, marked by a generational contrast, seem to reflect different steps in dietary change as described in the literature, suggesting an ongoing nutrition transition.

Keywords: Nutrition transition; Dietary patterns; Profiles of consumers; Clusters; French West Indies; Food consumption

Introduction

The nutrition transition sees the emergence of a “Western” dietary pattern characterized 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 [1]. This dietary shift has accompanied the development of a sedentary life-style, resulting in an increasing prevalence of obesity and nutrition-related chronic diseases [2]. As most of the Caribbean territories [3, 4], the French West Indies (Martinique and Guadeloupe) have a high prevalence of chronic diseases: 23% of adults are obese (27% of women, 18% of men), 38% have hypertension (39% of women, 38% of men), and 8% are pharmacologically treated for diabetes (9% of women, 7% of men) [5–7]. Despite the urgency regarding increasing rates of obesity and chronic diseases in the Caribbean [8, 9], very few studies have characterized the nutrition transition through dietary patterns in this area. In the Caribbean, energy availability has increased since the 1960s owing to a growing availability of animal-source foods, fats and oils, and simple sugars, while the availability of food sources with complex carbohydrates has consistently declined [8, 10–12]. The rare studies that have explored individual dietary intakes in the Caribbean report more frequent consumption of ultra-processed foods and red meat, and lower intakes of fruits, vegetables, traditional tubers, and fish among young adults compared with their elders [13, 14]. In the French West Indies, the two surveys assessing adults’ dietary intakes conducted in Martinique and Guadeloupe [15, 16] showed similar results, notably lower intake of fruits and vegetables, dairy products, and seafood in persons aged below 55 years, compared with older ones [16]. This suggests an ongoing nutrition transition, with young adults’ diets being less rooted in traditional dietary habits.

To develop appropriate public health policies, characterization of the nutrition transition step is needed. In-depth description of the persistence of traditional diet and the place of “globalized” diet in the Caribbean population could provide useful, accurate information to identify populations at higher nutritional risk. The study reported here aims at providing such information by identifying typical dietary patterns in the French West Indies and describing them according to health status, food supply practices, and socioeconomic characteristics.

Subjects and methods

Population

Subjects were participants aged 16 and over from the cross-sectional “Kannari survey: Health, Nutrition and Exposure to Chlordecone in French West Indies”, conducted on Guadeloupean and Martinican adults and children by Santé publique France (the French public health agency) in 2013–2014, and described elsewhere [15]. Briefly, the Kannari survey was based on a multistage stratified random sample of the Guadeloupean and Martinican populations to describe chlordecone food exposure and impregnation, health status, and food intakes in these populations. 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).

The Kannari survey was conducted in accordance with the Declaration of Helsinki guidelines, and the survey protocol received approval from the ethical research committee for the South-West and Overseas II (Comité de protection des personnes Sud-Ouest et Outre-Mer II, CPP No. 2-13-10) and the French data protection authority (Commission nationale de l’informatique et des libertés No. 913236). All the participants gave their informed consent.

Data collection

Demographic and socioeconomic characteristics, health status and food frequency data were collected through face-to-face interviews at home using standardized questionnaires and anthropometric data and blood pressure were measured. Trained dietitians conducted 24-h dietary recalls over the phone. Blood sample was collected for adults aged 18 and over.

Assessment of demographic and socioeconomic characteristics

Demographic characteristics were sex, age, location (Guadeloupe or Martinique), single-parent household, presence or not of at least one child in the household, and marital status.

Age categories, assessing the generational effect, were equally distributed before considering weights in the statistical analysis, as it was broken down into tertiles: 16–45 years, 46–60 years, and over 60 years. To better understand the age structure of the patterns, a sensitivity analysis was conducted using specific age cutpoints, broken down more finely categories: 16-30, 31-45, 46-60, 61-75, and above 75. Socioeconomic characteristics were education, employment status, and being whether or not a recipient of social assistance benefits. As income information was not available, social assistance benefit was used to identify the most deprived participants in our sample, in the form of a guaranteed minimum income. Education was recoded into three categories according to the highest qualification attained: low (no or primary school), middle (below high school), and high (equivalent to or higher than high school). Employment status was coded into three categories: unemployed and never-employed (disabled, homemakers and students), employed, and retired. Finally, occupation was classified using the six categories used by the French National Institute of Statistics and Economic Studies (INSEE) [17]: never-employed, manual worker, employee, intermediate profession (technician, skilled employee, teacher, nurse, etc.), managerial staff and self-employed (artisan, shopkeeper, company manager, farmer). If participants were retired or unemployed, their last occupation was recorded.

Assessment of dietary intake

Dietary data were collected using two non-consecutive randomly assigned 24-h dietary recalls. The distribution between weekdays and weekend days was balanced at the sample level. Participants were asked to describe in detail their food intake and amount 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 [18], representing more than 250 foods specific to the French West Indies (corresponding to 1000 generic foods) served in seven different portion sizes. In addition to

24-h dietary recalls, participants completed a qualitative 119-item food frequency questionnaire (FFQ), covering the last 12 months. Values for energy, macronutrients, and micronutrients such as calcium, iron, sodium, vitamins B12, C, and D were estimated using published nutrient databases [19] extended for French West Indian market foods and recipes. Beverage and food items were classified according to the information provided in the French Nutrition and Health Program guides yielding 64 food groups, aggregated into 39 food groups for this study. The Multiple Source Method (MSM) was used to estimate usual dietary intake [20]. With the MSM, usual dietary intakes were estimated using the amounts of consumption from 24-h dietary recalls combined with consumption frequencies declared in the FFQ, taking into account inter- and intra-individual variations, according to sex and age. This method let us keep in our analysis 30 subjects who completed only one 24-h dietary recall.

Erroneous quantities due to data entry errors were identified using day- and food-specific established thresholds. According to the percentage of erroneous data in declared quantities in the recall and the declaration of the subject the representativeness of the recall compared to his/her usual diet, the recall was corrected. Misreporters of energy intake (over- and under-reporters) were identified by the method proposed by Black [21]. Briefly, basal metabolic rate (BMR) was estimated using Mifflin equations [22] since a high prevalence of overweight and obesity was observed in our study sample. BMR was compared to energy intake by using a physical activity level of 1.55 x BMR as the cut-off to identify misreporters [21]. 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 under-reporters. No subject was identified as over-reporter in our sample. Under-reporters were excluded from the analyses.

Snacking occasion and characteristics

The eating occasions were categorized according to their nutritional content and self-reported time, following the methodology of Si Hassen *et al.* [23]. In the present study, we focused on overall snacking, defined as having at least one eating occasion apart from main meals during the last 24 hours, only on weekdays, because of variable and unusual eating behavior on weekends. Overall snacking was characterized by the occurrence, energy intake, energy density, and nutrient density. The energy density of snacks was calculated as the ratio of energy intake by the quantity of food declared, multiplied by 100, excluding the 10% lowest-calorie beverages. The nutrient density of snacks was assessed by the Nutrient-Rich Foods Index (NRF9.3) developed by Fulgoni *et al.* [24], calculated as the sum of the amount per 100 kcal divided by the daily values of nine nutrients and minerals to be encouraged (protein, fiber, vitamins A, C and E, calcium, iron, magnesium, and potassium) and subtracting the amount per 100 kcal divided by the daily values of three nutrients to be limited (saturated fat, added sugars, and sodium). The daily values were those used by Fulgoni, defined by the Food and Drug Administration [24].

Diet quality

The overall quality of the diet was evaluated using the Diet Quality Index-International (DQI-I) developed by Kim *et al.*, as it assesses several aspects of diet quality and allows international comparisons [25]. The DQI-I (range 0–100), including both nutrient- and food-group items, consists of 17 components grouped into four main categories: variety (overall food group variety and within-group variety for protein source), adequacy (vegetables, fruits, cereals, fiber, protein, iron, calcium, vitamin C), moderation (total fat, saturated fat, cholesterol, sodium, empty-energy foods) and overall balance (macronutrient ratio and fatty acid ratio).

Degree of food processing

Every food and beverage recalled by participants were classified in one of the four groups of the NOVA classification according to the extent and purpose of the industrial processing used in their production [26]: group 1, unprocessed or minimally processed foods; group 2, processed culinary ingredients; group 3, processed foods; group 4, ultra-processed foods. Ultra-processed foods are formulations made mostly or entirely from substances derived from foods and additives, with little if any intact group 1 food, such as soft drinks, sweet or savory packaged snacks, and pre-prepared frozen dishes. For the present study, the percentage of energy intake provided by the ultra-processed food group was estimated.

Food supply practices

Food supply practices were evaluated with a questionnaire for five food groups ("fruits, vegetables, roots and tubers", "fish and seafood", "red meat", "poultry", and "eggs"), categorized as "no purchase or no preference", "only or mainly in supermarkets", "only or mainly elsewhere than supermarkets". Also, overall home production (foods from their own production) and donation from someone outside the household were evaluated.

Health status

Body mass index (BMI) was calculated and categorized according to the World Health Organization (WHO) classification [27] and recorded into three categories: underweight or normal weight, overweight, and obese. Prevalence of metabolic syndrome (MetS) was determined according to the Joint Interim Statement [28] as meeting at least three of the following five criteria: (i) elevated waist circumference (≥94 cm for men and ≥80 cm for women), (ii) elevated triglycerides (≥150 mg/dL or drug treatment for elevated triglycerides), (iii) low HDL-cholesterolemia (<40 mg/dL for men and <50 mg/dL for women or dyslipidemia treatment), (iv) elevated blood pressure (systolic blood pressure ≥130 mm Hg and/or diastolic ≥85 mm Hg or antihypertensive drug treatment), and (v) elevated fasting glucose (≥100 mg/dL or antidiabetic medication). Waist circumference and blood pressure were measured for all participants, but biological data were available only for a subsample. For participants who agreed to blood sampling, fasting glucose, triglycerides, and HDL-cholesterol concentrations were measured. All the subjects were asked about medication for dyslipidemia, hypertension, and diabetes.

Statistical analysis

To identify different dietary patterns, we used a two-step procedure. First, a weighted principal component analysis (PCA) was applied to food group intakes (in g/d) adjusted for daily energy intake according to sex, using the residual method. Food groups with a factor loading coefficient under 0.25 being excluded, PCA was applied to the 25 food group intakes (among 39 available) detailed in Table 1. 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 [29], three dimensions were retained (Factor Loading available in **Supplementary Table 1**). Using these three dimensions, a clustering procedure was then performed by applying 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 t^2 and the cubic clustering criterion (CCC), were used to estimate the appropriate number of clusters [30]. Stabilization of the clusters was carried out to distribute the individuals better by clusters. Finally, to test the robustness of the clusters, kappa coefficients, markers of agreement between each simulated sample and the whole sample, were calculated for 50 randomly selected samples composed of three quarters of the whole sample, using an equal probability sampling method. Cluster analysis yielded groups, interpreted as dietary patterns, labeled according to their main food intakes. Clusters were described according to their main nutritional characteristics (food group and nutrient intakes adjusted for daily energy intake without alcohol, DQI-I, percentage of energy intake provided by the ultra-processed food group, occurrence of overall snacking and, energy intake, energy density and nutrient density of overall snacking). Multivariable logistic regressions were performed by calculating adjusted percentages and Odds Ratios (ORs), 95% confidence intervals (95% CI) to determine the strength of the association between each pattern membership (belonging to on this pattern or not) and demographic and socioeconomic characteristics, health status and food supply practices. Models were adjusted for sex, location (Guadeloupe or Martinique), age, employment status, education, social assistance benefits, presence of at least one child in the household, single-parent household, marital status and body mass index (BMI).

Sensitivity analyses were also conducted. First, we described our patterns stratified by age (“under 45” and “aged 45 or above”). To assess whether identified dietary patterns were different between Guadeloupe and Martinique, we also conducted stratified PCA on location. Finally, we performed PCA excluding alcoholic beverages.

To take into account the complex survey design, weighting was 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, using the iterative proportional fitting procedure according to the French national census reports [31]. In all the analyses, we used specific survey procedures to take into account weighting and stratification.

For all analyses, a *p*-value of <0.05 was considered statistically significant. Data management and statistical analyses were performed using SAS (version 9.4; SAS Institute, Inc., Cary, NC, USA.).

Results

Among the 1,799 subjects who participated in the Kannari study, 458 did not complete a 24-h dietary recall and 197 were energy under-reporters leaving 1,144 subjects (≥16 y) included in the analyses (**Supplementary Figure 1**).

The great majority were born in either Guadeloupe or Martinique. Our sample was equitably distributed between Guadeloupe and Martinique and 57% of respondents were women (**Supplementary Table 2**). Approximately 44% of the participants were aged under 46 years, and 27% were aged above 60. Almost 40% of the participants were living with at least one child in their household, and 6% were single parents. Regarding socioeconomic characteristics, 32% of the participants were unemployed or never-employed. Half of the sample were employees, and only 7% were managerial staff. The low-educated formed 44%, the high-educated 37%, and 19% received social assistance benefits. Regarding health status, 21% of the sample were obese, 40% had hypertension, 11% had diabetes, and MetS was identified in 23%.

Cluster analysis yielded four groups. These clusters were interpreted as four dietary patterns and labeled according to their main food intakes as “prudent”, “traditional”, “convenient” and “transitioning” patterns, representing respectively, 25%, 24%, 31%, and 20% of the sample. **Table 1** presents the daily intakes adjusted for energy intake of the 25 food groups included in the PCA across dietary patterns. **Table 2** and **Figure 1** describe the main nutritional characteristics of each dietary pattern, and **Tables 3, 4, and 5** describe demographic and socioeconomic factors, health status and supply practices, respectively. Odds Ratios and 95% CI to assess the associations between pattern membership and demographic and socioeconomic factors, health status and supply practices are presented in **Supplementary Tables 3, 4 and 5,** respectively.

The "prudent" pattern

The participants belonging to the cluster displaying a "prudent" pattern had the highest intakes of rice, whole-grain products, seafood and yogurts, and the lowest intake of fatty and sweet products. They also had high intakes of fruits, vegetables and legumes, and low intake of tubers, sweetened beverages, biscuits, cakes, and pastries. Those displaying this "prudent" pattern had the highest intake of calcium, the lowest intake of free sugars, and a high DQI-I. Complex carbohydrates and proteins made up, respectively, 29% and 19% of their daily energy intake. "Prudent pattern" subjects had the lowest percentage of energy provided by ultra-processed food and their snacks had the highest nutritional density ($p=0.02$, data not shown). A high percentage (45%) bought their fruits, vegetables, roots, and tubers mainly in supermarkets, and 77% had food donated by someone outside the household, higher than other patterns. Overall, "Prudent pattern" participants had similar sociodemographic and economic characteristics to those of the overall sample, except for the higher percentages of Guadeloupeans (62%) and individuals living in couples. A high percentage of high-educated individuals was observed, not significantly higher than in other patterns. Regarding health status, a high percentage of obesity was observed, but not significantly higher compared with other patterns.

The "traditional" pattern

Participants belonging to this cluster displaying a "traditional" pattern had the highest consumption of fruits, vegetables, tubers, fish, fatty and sweet products, and traditional French West Indian dishes, and the lowest consumption of starches, red and processed meat, poultry, sweetened beverages, alcoholic beverages, and snacks and fast foods. In addition, they had the lowest energy intake, and total and simple carbohydrates made up respectively 48% and 22% of the total energy intake. Compared with other subjects, "traditional" pattern subjects had the highest DQI-I, with a high score for moderation and overall balance components. In this pattern, only 10% of the participants ate no breakfast, and the energy provided by snacking was lower than for the other patterns (p=0.04, data not shown). A high percentage of subjects bought their supplies mainly in supermarkets, except for fish and seafood, mainly bought elsewhere. This pattern was shaped mostly by women and older subjects.

The "convenient" pattern

The participants belonging to the cluster displaying a "convenient" pattern had the lowest intakes of fruit, vegetable, tubers, whole-grain foods, fish and seafood, yogurts and traditional French West Indian dishes, and the highest intakes of potatoes, pasta, poultry, biscuits, cakes and pastries, snacks and fast foods and sweetened beverages. The contribution of lipids to the daily energy intake was higher than in the other patterns, especially saturated fatty acids, and the protein contribution was lower. "Convenient" pattern subjects also had the lowest intakes of fiber, calcium, vitamins D and B12, and the highest intake of free sugars compared with the other patterns. This resulted in the lowest DQI-I found in the sample, with a low variety score. The percent energy intake provided by ultra-processed foods was the highest. Almost 30% of the subjects in this pattern ate no breakfast, and 59% had a snack at least once in the day. Snacking made up 24% of the daily energy intake, but its nutritional density was low. In this pattern, subjects bought their fruits, vegetables, roots, and tubers mainly in supermarkets (p=0.01), and had a low percentage of home-produced foods. This "convenient" pattern was mainly composed of young participants (<46 years).

The "transitioning" pattern

The participants belonging to the cluster displaying a "transitioning" pattern had the highest consumption of bread, red and processed meat, sauces and alcoholic beverages, and the lowest intakes of whole grain products, but also of biscuits, cakes, and pastries. Subjects also had high intake of sweetened beverages, but conversely high intakes of tubers, legumes, fish, and offal. In addition, 45% of their dishes were traditional French West Indian dishes. They had the highest intakes of fiber, sodium and iron, and the highest energy intake, of which 31% was provided by complex carbohydrates. This resulted in an intermediate DQI-I of 61 points. A low percentage of snacking was found in subjects with this pattern (50%) and their snacks contributed only slightly to the daily energy intake. This "transitioning" pattern was mainly shaped by men and middle-aged individuals. In this "transitioning" pattern, the prevalence of overweight was high (41%), as was the prevalence of MetS (35%), significantly higher compared with other patterns.

To understand the age structure, the contribution of each pattern to each age category was assessed (**Figure 2**). The "convenient" pattern was found in almost 70% of the subjects aged under 30 and in 45% of those aged between 31 and 45. The "prudent" pattern also formed a high percentage of the subjects aged under 46, and was present in those aged between 46 and 60. The "transitioning" pattern was strong at ages above 45 and especially above 60. Finally, the "traditional" pattern comprised almost the majority of subjects aged 61 to 75 and most of those over 75.

In sensitivity analysis, the same four patterns were found in the PCA stratified for location (Guadeloupe and Martinique) (data not shown). Also, the same patterns occurred when alcoholic beverages were excluded from the PCA (data not shown). Finally, sensitivity analysis stratified by age (**Supplementary Table 6**) led to different profiles inside patterns according to age (under 45 years or aged 45 and above). In all four patterns, education level profiles were different according to age group, the younger persons being more educated than the older ones, i.e., above age 45 years. Also, compared with other patterns, the "convenient" pattern had the highest percentage of unemployed or never-employed persons among the above 45 years group. Finally, a high percentage of obesity in the "traditional" pattern was found, mainly in younger individuals (under 45 years).

Discussion

In this study conducted in the French West Indies, we identified the following four dietary patterns: “prudent”, “traditional”, “convenient” and “transitioning”. Each pattern exhibited specific nutritional, demographic, and socioeconomic characteristics.

Four co-existing dietary patterns

Two of our identified dietary patterns, which we labeled “prudent” and “convenient”, have been found worldwide and are largely described [32–34]. Consistent with the literature, our “prudent” pattern had high intakes of fruits, vegetables, legumes, rice, whole grains, fish, and seafood. However, we detected some differences regarding the intake of red meat. The association between consumption of meat and socioeconomic position seems to change during nutrition transition: higher socioeconomic status (SES) is first associated with higher meat intakes, and then with lower meat intakes at an advanced step in the nutrition transition, which may be partly due to changes in meat representation in society [35]. Meat is an essential food in typical French West Indian meals, associated with pleasure and health by its contribution to protein intake [36]. This may explain the occurrence of red meat intakes in our “prudent” pattern. The “convenient” or “Western” pattern is generally characterized by high intakes of red and processed meat, refined grains, sweets, and soft drinks, and low micronutrient intakes, leading to low diet quality [32–34]. Although consistent, our “convenient” pattern included some specific features: subjects did not have high intakes of red meat, whereas their intakes of poultry were high. This may be due to the high availability and low prices of imported frozen poultry [37]. To our knowledge, only one study, a case-control study on 516 Jamaican men, has identified dietary patterns in the Caribbean [38]. In concordance with our results, they identified four patterns including a “vegetable and legume” pattern similar to our “prudent” pattern and a “meat” pattern similar to our “convenient” pattern, with high loadings for processed meat and poultry (0.57 and 0.39, respectively) but not for red meat (0.25) [38]. The identification of such "prudent" and "convenient" patterns in French West Indies is further evidence of a worldwide homogenization of dietary patterns due to international trade agreements and the globalization of food production and distribution increasing dependence on imported processed foods [2, 39]. However, a "traditional" pattern remained in the French West Indies, reflecting specific cultural habits such as high intakes of fruits, vegetables, tubers and fish, and low intakes of starches, processed meat, sweetened beverages, snacks and fast foods, consistent with the composition of typical meals [36] and the results of the work conducted by the Health Agency of Guadeloupe in 2010, which identified a similar traditional profile [40]. To our knowledge, no other study in the Caribbean has identified a "traditional" pattern, yet brief descriptions of the Caribbean diet are consistent with our findings, mentioning tuber, white bread, rice, plantains, fish, and bean dishes as traditional foods [14, 41]. In agreement with results obtained in 2010 in Guadeloupe [40], the diet quality of subjects in our "traditional" pattern was high, just as high as for the "prudent" one, which could be due to the good balance of typical meals [36]. Previous studies have identified traditional diets with high diet quality such as Mediterranean-type diets, associated with reduced health risks [42]. Further studies assessing associations between French West Indies' traditional diet and chronic diseases are needed to evaluate whether this diet, affordable and culturally and socially acceptable, may be promoted to fight against chronic diseases and obesity. Finally, concordant with studies that identified a "transitioning" pattern, mixing traditional and "modern" foods [43, 44], the present study identified a pattern characterized by high intakes of traditional French West Indies foods (tubers, legumes, fish, and offal), coexisting with high intakes of "Western" foods (sweetened beverages, butter, processed meat, bread, pasta, and sauces). Our finding is consistent with a recent study conducted among 100 Puerto Rican women, where foods contributing to macronutrient intake reflected both traditional Puerto Rican diets and "Western" diets [41]. This "transitioning" pattern suggests an ongoing nutrition transition in the French West Indies, with populations moving from a traditional to a convenient diet.

Individuals characteristics of the dietary patterns

First, a difference according to sex was found for the “traditional” pattern, mainly shaped by women, and the “transitioning” pattern, by men. Our result was consistent with published studies showing healthier dietary behavior in women [32, 45, 46]. Also consistent with the literature [1, 32, 33] and with the only study assessing associations between sociodemographic factors and frequency of consumption of some foods in a Caribbean context [14], we observed a generational effect, younger subjects adopting new dietary patterns, while the traditional dietary pattern persisted in older participants, and the transitioning pattern in middle-aged ones. We can, therefore, hypothesize that nutrition transition in French West Indies started in younger individuals (<45 years, as shown in the sensitivity analysis) who changed their diet to a “modern” one, may be due to readier adoption of “Westernized” lifestyles, related to different responses to social and economic changes according to the generation [1], and to different responses to advertising and marketing, the youngest being the most receptive [47]. Our “prudent” pattern largely comprised high-educated persons, concordant with the literature [32, 33]. Education is associated with a better understanding of the importance of nutritional information messages and the ability to appropriate them, leading to healthier dietary patterns in high-educated individuals [48, 49]. The high percentage of snacking and their high nutritional density in our “prudent” pattern is consistent with findings of a French mainland study showing positive associations between education and prevalence and nutritional density of snacks [23]. Finally, few associations with food supply practices were significant while we may have expected an association with the ‘convenient’ pattern as literature shown changes in food supply as one of the characteristics of nutrition transition, with supermarket becoming the major source of supply for food instead of market [2]. A recent study conducted by our team showed that retail expansion impacted the nutritional quality of food imports in the French West Indies: the spread of super and hypermarkets was associated with not only larger imports of animal protein, saturated fat, and sugar, but also a larger per-capita fiber supply [50]. The lack of significant association in our study may be due to the food supply practice questionnaire, which included only five food groups, contributing to chlordecone exposure.

Unlike previous works [32], no association between the “convenient” pattern and health status was found in our study, which may result from the individuals’ young age in this pattern, and the cross-sectional design of our study.

Limitations

The interpretation of our results must take into account several limitations. First, an inherent limitation of a cross-sectional design is the impossibility of inferring causal relationships, and potential reverse causality. The rather small size of our sample may question about the generalizability of our findings, yet the Kannari survey was carefully designed to be representative and analyses were weighted according to national census data, our final sample fitting the general population distribution, which allows to limit the bias. Dietary recalls conducted over the phone may have caused bias of reporting food consumption among low-educated participants, some of whom being probably innumerate and illiterate. However, the use of the illustrated booklet with more than 250 photos, corresponding to 1000 generic foods, served in seven different portion sizes, and the fact that recalls were conducted by trained dietitians have limited the bias. Also, 15% of the subjects were identified as energy under-reporters and excluded from the analysis sample: compared with included subjects, the excluded participants were younger, with a higher percentage of unemployed or never-employed individuals [51]. Finally, some other drivers of the nutrition transition, such as characteristics of the foodscape (neighborhood densities of fast-food outlets or supermarkets) and the food availability, could not be considered in our models. However, these characteristics may be associated with the dietary patterns, especially the 'convenient' one, as retail expansion is associated with animal protein, saturated fat, and sugar imports in the French West Indies [50].

Conclusion

The diversified dietary patterns identified in the French West Indies seem to reflect different steps of dietary change as previously described in the literature, suggesting an ongoing nutrition transition. These patterns co-exist with a generational contrast, providing useful information for public health actions targeting population groups at higher nutritional risk.

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

Author contributions: The authors' responsibilities were as follows: Z.C. designed the study, performed statistical analysis, interpreted data, and drafted the manuscript; B.A., M.P., E.L., Y.M.P., M.J.A., and N.D. were involved in the interpretation of data, and helped to draft the manuscript; C.M. was involved in the conception and design of the study, supervision of statistical analysis and interpretation of data, and helped to draft the manuscript. All authors read and approved the final manuscript.

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Table 1. Daily intakes adjusted for energy intake of the 25 food groups included in the principal component analysis (PCA) across clusters and in the overall sample of Guadeloupe and Martinique subjects (≥16y) from the Kannari study (*n* = 1,144)[1]

	All	Prudent	Traditional	Convenient	Transitioning
n (%)		253 (25.0)	365 (24.2)	291 (31.2)	235 (19.6)
Intakes of food groups, adjusted for energy intake (g/day)[2]	**Mean ± SEM**	**Mean ± SEM**	**Mean ± SEM**	**Mean ± SEM**	**Mean ± SEM**
Fruit	122.4 ± 4.7	154.0 ± 9.9	182.3 ± 10.9	58.0 ± 4.5	110.3 ± 7.2
Vegetable	142.5 ± 4.0	177.2 ± 9.0	185.6 ± 7.7	92.0 ± 4.7	125.2 ± 6.6
Bread and rusk	58.8 ± 1.6	48.3 ± 2.6	52.2 ± 2.0	50.1 ± 2.6	94.0 ± 3.6
Potato	19.0 ± 0.5	18.0 ± 0.9	12.9 ± 0.6	24.1 ± 1.1	20.0 ± 0.7
Tuber (other than potato)	66.4 ± 2.4	45.2 ± 2.9	102.1 ± 4.8	35.2 ± 2.8	98.7 ± 6.3
Pasta	35.9 ± 1.8	21.8 ± 2.2	20.9 ± 1.9	59.9 ± 3.9	34.4 ± 3.9
Rice	73.2 ± 2.7	112.3 ± 5.8	43.5 ± 2.4	69.7 ± 4.5	65.8 ± 5.4
Semolina and other cereals	17.5 ± 1.3	14.8 ± 2.8	14.5 ± 1.5	11.4 ± 1.4	34.2 ± 4.1
Legume	34.1 ± 1.5	46.4 ± 3.5	21.3 ± 1.2	25.6 ± 1.8	47.6 ± 4.1
Whole-grain product	8.0 ± 0.8	16.3 ± 2.3	10.7 ± 1.8	3.3 ± 1.2	1.7 ± 0.5
Fish	43.5 ± 1.3	41.8 ± 2.4	56.1 ± 2.1	27.2 ± 1.6	56.1 ± 3.1
Seafood	7.3 ± 0.7	16.3 ± 2.2	4.1 ± 0.7	3.5 ± 0.5	6.1 ± 1.2
Red meat	43.1 ± 1.0	46.6 ± 2.5	31.8 ± 1.1	42.5 ± 1.5	53.4 ± 2.2
Poultry	56.4 ± 1.7	56.4 ± 3.1	38.9 ± 2.2	69.2 ± 3.4	57.4 ± 3.6
Processed meat	18.1 ± 0.6	14.1 ± 0.9	13.6 ± 0.8	20.6 ± 1.2	24.8 ± 1.5
Offal	9.1 ± 0.4	8.0 ± 0.6	9.9 ± 0.8	6.0 ± 0.5	14.5 ± 1.2
Yogurts	23.6 ± 1.6	42.1 ± 4.1	26.4 ± 2.6	12.9 ± 2.6	13.6 ± 2.5
Salad dressing and sauce	21.9 ± 0.5	21.3 ± 0.9	20.6 ± 0.7	17.9 ± 0.8	30.9 ± 1.0
Butter	2.6 ± 0.1	2.1 ± 0.2	2.0 ± 0.2	2.4 ± 0.3	4.2 ± 0.4
Snacks and fast food	26.5 ± 1.3	22.1 ± 2.2	15.8 ± 1.0	43.1 ± 3.0	18.9 ± 2.3
Biscuits, cakes and pastries	33.4 ± 1.4	29.2 ± 2.2	32.4 ± 2.2	47.0 ± 3.2	18.2 ± 2.3

Fatty and sweet products (chocolate, ice cream, etc.)	11.9 ± 0.7	6.9 ± 0.8	16.5 ± 1.5	13.8 ± 1.5	9.6 ± 1.4
Non-alcoholic and non-sweetened beverage (water, coffee, tea)	1398.0 ± 21.8	1554.4 ± 43.6	1310.8 ± 27.7	1223.2 ± 26.4	1584.5 ± 61.4
Sweetened beverage and juice	188.3 ± 6.2	132.2 ± 7.0	123.9 ± 5.5	279.5 ± 12.7	194.7 ± 12.4
Alcoholic beverage	40.3 ± 4.1	41.0 ± 7.1	15.6 ± 2.2	26.8 ± 6.5	91.1 ± 14.3

Values are presented as mean ± standard error of mean (SEM).

[1] Sex-specific data weighted for education, marital status, birthplace, presence of at least one child in the household, living in an area of chlordecone contamination (coastline and inland), and urban size, using 2012 national census.

[2] 25 food groups used in the weighted principal component analysis (PCA). All *p*-trends < 0.01.

Table 2. Selected nutritional characteristics across clusters and in the overall sample of Guadeloupe and Martinique subjects (≥16 y) from the Kannari study (*n* = 1,144) [1, 2]

	All	Prudent	Traditional	Convenient	Transitioning
	Mean ± SEM or % ± SE	Mean ± SEM or % ± SE	Mean ± SEM or % ± SE	Mean ± SEM or % ± SE	Mean ± SEM or % ± SE
Energy intake (kcal/day)	1584.2 ± 18.1	1560.5 ± 29.0	1414.6 ± 21.9	1603.8 ± 35.9	1792.9 ± 44.7
Energy intake without alcohol (kcal/day)	1554.9 ± 17.2	1531.5 ± 28.7	1402.4 ± 21.1	1584.2 ± 35.1	1726.9 ± 41.3
Free sugars (g/day) [3]	40.8 ± 1.1	30.5 ± 1.4	35.7 ± 1.1	54.6 ± 2.2	38.2 ± 2.0
Fiber (g/day) [3]	16.0 ± 0.2	17.2 ± 0.4	16.7 ± 0.3	13.0 ± 0.2	18.5 ± 0.4
Calcium (mg/day) [3]	654.6 ± 7.6	719.4 ± 17.0	669.7 ± 11.1	590.6 ± 12.2	655.3 ± 15.7
Sodium (mg/day) [3]	2228.0 ± 20.5	2322.8 ± 49.0	2017.7 ± 24.7	2148.8 ± 34.0	2493.2 ± 36.6
Iron (mg/day) [3]	10.5 ± 0.1	11.3 ± 0.2	9.6 ± 0.1	9.7 ± 0.2	11.7 ± 0.2
Vitamin C (mg/day) [3]	116.4 ± 4.1	113.0 ± 7.4	116.1 ± 3.6	118.8 ± 10.7	117.2 ± 6.6
Alcohol (g/day) [3]	4.0 ± 0.4	4.0 ± 0.7	1.8 ± 0.3	2.6 ± 0.6	8.6 ± 1.2
Vitamin D (µg/day) [3]	3.2 ± 0.1	3.0 ± 0.2	3.8 ± 0.1	2.6 ± 0.1	3.5 ± 0.2
Vitamin B12 (µg/day) [3]	4.4 ± 0.1	4.6 ± 0.1	4.3 ± 0.1	4.0 ± 0.1	5.1 ± 0.2
Diet Quality Index - International (0–100 points)	60.8 ± 0.4	64.0 ± 0.7	65.4 ± 0.6	54.6 ± 0.5	60.8 ± 0.8
Moderation (0–30 points)	17.1 ± 0.2	17.6 ± 0.4	18.3 ± 0.3	16.4 ± 0.2	16.3 ± 0.5
Variety (0–20 points)	16.5 ± 0.1	17.4 ± 0.3	17.6 ± 0.2	14.9 ± 0.2	16.3 ± 0.3
Adequacy (0–40 points)	26.1 ± 0.2	28.1 ± 0.5	28.1 ± 0.4	22.4 ± 0.3	27.2 ± 0.3
Overall balance (0–10 points)	0.3 ± 0.1	0.2 ± 0.1	0.5 ± 0.1	0.3 ± 0.1	0.5 ± 0.1
French West Indian dishes (% of all the dishes consumed)	39.2 ± 2.0	35.1 ± 4.0	52.3 ± 3.7	27.8 ± 3.9	45.2 ± 4.3
% of energy intake provided by ultra-processed foods (% of energy/day)	24.2 ± 0.5	20.6 ± 0.9	21.2 ± 0.7	31.4 ± 1.1	21.2 ± 1.0

No breakfast (%)	18.9 ± 1.9	18.9 ± 4.1	9.6 ± 2.5	29.8 ± 4.1	13.1 ± 3.3
% have a snack at least once in the day	56.2 ± 2.3	61.8 ± 4.7	52.3 ± 4.0	58.6 ± 4.5	50.3 ± 5.1
% of energy provided by snacking occasion (% of energy/day)	20.5 ± 1.3	21.0 ± 2.2	17.6 ± 1.2	23.7 ± 3.0	17.7 ± 2.6
Energy density of snacking occasion, without low-calorie beverages (10% lowest caloric beverages) (kcal/100 g)	291.6 ± 12.0	301.5 ± 27.6	294.5 ± 21.1	281.3 ± 23.5	291.47 ± 35.8
Nutritional density of snacking occasion (Nutrient-Rich Foods Index NRF9.3)	37.1 ± 4.1	52.7 ± 11.1	37.7 ± 6.0	29.6 ± 6.9	25.7 ± 6.2

Values are presented as mean ± standard error of mean (SEM) or percentage (%) ± standard error (SE), as appropriated.

[1] Sex-specific data weighted for education, marital status, birthplace, presence of at least one child in the household, living in an area of chlordecone contamination (coastline and inland), and urban size, using 2012 national census.

[2] All *p*-trends < 0.01, except for vitamin C, overall balance, having a snack, energy provided by snacking occasion, energy density of snacking occasion, and nutritional density of snacking occasion (p-trend > 0.05).

[3] Adjusted for daily energy intake without alcohol

Table 3. Adjusted demographic and socioeconomic characteristics across clusters and in the overall sample of Guadeloupe and Martinique subjects (≥16 y) from the Kannari study (n = 1,144) [1]

	All	Prudent		Traditional		Convenient		Transitioning	
	% (SE) [2]	% (SE) [2]	***p*-value**[3]	% (SE) [2]	***p*-value**[3]	% (SE) [2]	***p*-value**[3]	% (SE) [2]	***p*-value**[3]
Women	57.4 (2.0)	57.9 (4.5)	0.67	90.0 (2.5)	< 0.01	53.3 (4.4)	0.98	17.1 (3.3)	< 0.01
Location			< 0.01		0.49		0.06		0.20
Guadeloupe	48.5 (2.1)	61.5 (4.4)		49.2 (4.5)		41.2 (4.9)		40.6 (5.5)	
Martinique	51.5 (2.1)	38.5 (4.4)		50.8 (4.5)		58.8 (4.9)		59.4 (5.5)	
Age class			0.08		< 0.01		< 0.01		< 0.01
16–45 years	37.1 (1.5)	34.3 (3.3)		26.3 (3.3)		59.4 (3.4)		24.8 (4.4)	
46–60 years	29.8 (1.6)	35.0 (3.5)		35.9 (3.5)		12.1 (3.1)		39.4 (4.5)	
>60 years	33.1 (0.8)	30.7 (1.1)		37.8 (2.6)		28.5 (1.2)		35.8 (2.6)	
Education			0.37		0.72		0.55		0.72
Low	49.3 (2.0)	46.9 (3.8)		47.8 (4.5)		51.6 (4.4)		51.4 (4.9)	
Middle	17.2 (1.4)	14.9 (3.1)		21.3 (3.8)		18.5 (3.6)		12.4 (4.1)	
High	33.5 (1.9)	38.2 (3.8)		30.9 (4.1)		29.9 (4.2)		36.2 (5.1)	
Employment status			0.26		0.77		0.06		0.21
Unemployed, disabled, homemakers or students	27.6 (1.6)	26.8 (3.5)		22.5 (3.5)		34.6 (4.2)		27.2 (4.1)	
Active	41.4 (1.7)	40.4 (3.6)		44.6 (3.8)		35.7 (4.3)		45.3 (4.6)	
Retired	31.0 (0.9)	32.8 (1.1)		32.9 (2.3)		29.7 (1.1)		27.5 (2.6)	
Occupational categories			0.63		0.41		0.62		0.30
Self-employed	14.3 (1.4)	14.1 (3.2)		11.8 (3.2)		11.3 (3.2)		22.8 (4.2)	
Managerial staff	7.0 (1.0)	6.0 (2.2)		7.4 (2.1)		7.4 (2.3)		6.6 (2.7)	

Intermediate profession	8.6 (1.1)	11.7 (2.5)		5.9 (2.2)		10.6 (2.5)		6.2 (2.6)	
Employee	53.1 (2.0)	48.6 (4.4)		60.7 (4.1)		54.7 (4.9)		44.9 (5.5)	
Manual worker	9.0 (1.0)	11.1 (2.7)		7.1 (1.7)		6.4 (2.2)		12.5 (3.4)	
Never-employed	8.0 (1.0)	8.5 (2.5)		7.1 (2.3)		9.6 (2.8)		7.0 (2.5)	
Receive social assistance benefits	16.5 (1.4)	16.6 (3.2)	0.94	18.1 (3.4)	0.42	12.6 (3.6)	0.29	19.0 (4.4)	0.58
At least one child in the household	33.8 (1.8)	34.6 (3.6)	0.93	27.8 (3.7)	0.11	37.4 (4.4)	0.43	37.0 (4.8)	0.64
Single-parent household	4.9 (0.7)	5.6 (1.7)	0.63	2.4 (1.6)	0.59	6.6 (2.2)	0.69	5.8 (1.6)	0.58
Marital status			< 0.01		0.19		0.02		0.96
Single	51.2 (2.0)	38.7 (4.1)		58.6 (4.4)		58.9 (4.5)		46.2 (4.7)	
Living in couple	48.8 (2.0)	61.3 (4.1)		41.4 (4.4)		41.1 (4.5)		53.8 (4.7)	

Values are presented as percentage (standard error, SE)

[1] Sex-specific data weighted for education, marital status, birthplace, presence of at least one child in the household, living in an area of chlordecone contamination (coastline and inland), and urban size, using 2012 national census.

[2] Adjusted for sex, location (Guadeloupe or Martinique), age, employment status, education, social assistance benefits, presence of at least one child in the household, single-parent household, marital status, and body mass index (BMI) (except for the studied characteristic)

[3] Multivariable logistic regression assessing the association between the characteristic and each pattern membership (belonging to this pattern or not)

Table 4. Adjusted health status across clusters and in the overall sample of Guadeloupe and Martinique subjects (≥16 y) from the Kannari study (n = 1,144) [1]

	All	Prudent		Traditional		Convenient		Transitioning	
	% (SE) [2]	% (SE) [2]	**p-value[3]**	% (SE) [2]	**p-value[3]**	% (SE) [2]	**p-value[3]**	% (SE) [2]	**p-value[3]**
Body mass index class			0.50		0.79		0.37		0.51
Underweight or normal weight	42.7 (2.0)	40.2 (4.5)		42.0 (4.2)		48.1 (4.8)		40.1 (5.2)	
Overweight	34.9 (2.0)	34.4 (4.6)		32.4 (4.0)		33.4 (4.4)		41.3 (5.2)	
Obese	22.4 (1.6)	25.4 (3.3)		25.6 (4.1)		18.5 (3.8)		18.6 (3.7)	
Hypertension (140/90 mm Hg)	43.6 (1.9)	45.6 (4.0)	0.60	44.3 (4.1)	0.84	39.8 (4.3)	0.33	44.7 (5.4)	0.80
Diabetes	12.7 (1.3)	11.8 (2.5)	0.61	13.9 (3.1)	0.92	12.5 (2.5)	0.98	12.7 (2.6)	0.59
Metabolic syndrome	26.0 (1.7)	25.7 (3.7)	0.79	23.1 (3.2)	0.35	23.4 (3.2)	0.25	34.9 (4.5)	0.02

Values are presented as percentage (standard error, SE)

[1] Sex-specific data weighted for education, marital status, birthplace, presence of at least one child in the household, living in an area of chlordecone contamination (coastline and inland) and urban size, using 2012 national census.

[2] Adjusted for sex, location (Guadeloupe or Martinique), age, employment status, education, social assistance benefits, presence of at least one child in the household, single-parent household, marital status, and body mass index (BMI) (except for the studied characteristic)

[3] Multivariable logistic regression assessing the association between the characteristic and each pattern membership (belonging to this pattern or not)

Table 5. Adjusted food supply practices across clusters and in the overall sample of Guadeloupe and Martinique subjects (≥16 y) from the Kannari study (n = 1,144) [1]

	All	**Prudent**		**Traditional**		**Convenient**		**Transitioning**	
	% (SE) [2]	% (SE) [2]	***p*-value**[3]	% (SE) [2]	***p*-value**[3]	% (SE) [2]	***p*-value**[3]	% (SE) [2]	***p*-value**[3]
Home-produced foods	49.1 (2.0)	50.4 (4.4)	0.69	52.1 (4.1)	0.51	44.6 (4.7)	0.34	48.4 (5.1)	0.94
Donation from someone outside the household	69.0 (1.9)	77.1 (3.6)	0.02	67.3 (4.1)	0.43	72.4 (4.1)	0.84	56.7 (5.3)	0.01
Purchase									
Fruits, vegetables, roots, and tubers			0.88		0.13		0.04		0.36
No purchase or no preference	30.5 (1.9)	29.7 (4.2)		36.2 (3.9)		21.2 (4.0)		34.9 (4.8)	
Only or mainly in supermarkets	42.4 (2.0)	44.7 (4.4)		37.3 (4.3)		50.6 (4.3)		36.7 (4.8)	
Only or mainly elsewhere than supermarkets	27.1 (1.9)	25.6 (3.9)		26.5 (3.9)		28.2 (4.2)		28.4 (5.0)	
Fish and seafood			0.63		0.10		0.31		0.56
No purchase or no preference	25.0 (1.8)	22.6 (3.9)		26.1 (3.9)		23.2 (4.2)		29.2 (4.5)	
Only or mainly in supermarkets	40.7 (2.0)	44.3 (4.4)		32.8 (4.0)		47.9 (4.8)		38.5 (5.3)	
Only or mainly elsewhere than supermarkets	34.3 (1.9)	33.1 (4.1)		41.1 (4.2)		29.0 (4.1)		32.3 (5.2)	
Red meat			0.66		0.06		0.53		0.81
No purchase or no preference	24.7 (1.8)	21.7 (3.9)		31.3 (4.1)		19.8 (4.4)		24.9 (4.8)	
Only or mainly in supermarkets	46.8 (2.0)	51.1 (4.5)		40.2 (4.2)		48.6 (4.8)		49.3 (5.4)	
Only or mainly elsewhere than supermarkets	28.5 (1.8)	27.2 (3.8)		28.5 (4.0)		31.6 (4.1)		25.8 (5.0)	
Poultry			0.54		0.43		0.88		0.89
No purchase or no preference	21.2 (1.7)	17.4 (3.5)		24.1 (4.0)		22.3 (4.0)		20.4 (4.5)	
Only or mainly in supermarkets	68.4 (1.9)	71.4 (4.0)		67.0 (4.3)		66.8 (4.4)		68.9 (5.6)	
Only or mainly elsewhere than supermarkets	10.3 (1.3)	11.2 (2.8)		8.9 (2.3)		10.9 (2.6)		10.7 (4.4)	

Eggs			0.59		0.66		0.60		0.14
No purchase or no preference	26.1 (1.9)	23.2 (3.9)		22.7 (3.2)		25.7 (4.4)		35.7 (5.2)	
Only or mainly in supermarkets	59.8 (2.0)	60.6 (4.5)		63.6 (4.1)		62.3 (4.7)		49.5 (5.5)	
Only or mainly elsewhere than supermarkets	14.1 (1.5)	16.2 (3.5)		13.7 (3.4)		12.0 (3.1)		14.8 (3.9)	

Values are presented as percentage (standard error, SE)

[1] Sex-specific data weighted for education, marital status, birthplace, presence of at least one child in the household, living in an area of chlordecone contamination (coastline and inland), and urban size, using 2012 national census.

[2] Adjusted for sex, location (Guadeloupe or Martinique), age, employment status, education, social assistance benefits, presence of at least one child in the household, single-parent household, marital status, and body mass index (BMI).

[3] Multivariable logistic regression assessing the association between the characteristic and each pattern membership (belonging to this pattern or not)