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Definition of a healthy dietary variety index in 4 years old children and its related factors

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O presente trabalho foi efetuado no âmbito da coorte Geração XXI, desenvolvido no Departamento de Epidemiologia Clínica, Medicina Preditiva e Saúde Pública da Faculdade de Medicina do Porto e pelo Instituto de Saúde Pública da Universidade do Porto.

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Esta dissertação tem por base um manuscrito, no qual colaborei ativamente na operacionalização da hipótese, análise e interpretação dos dados e fui responsável pela redação das suas primeiras versões:

I. **Association of child and family characteristics with a healthy dietary variety index in 4 years old children**

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Manuscript

LIST OF ABBREVIATIONS

BMI – Body Mass Index
FAO – Food and Agricultural Organization
US – United States
VIT – Variety Index Score
WHO – World Health Organization

RESUMO

Introdução

Com a prática de uma alimentação variada é mais fácil atingir as recomendações nutricionais, contudo a variedade alimentar nem sempre é considerada na definição de índices de qualidade alimentar construídos para os países desenvolvidos. Estudos de base populacional com informação de várias exposições, avaliadas a partir de uma abordagem prospetiva, em crianças de idade pré-escolar vai reforçar a identificação precoce dos determinantes da variedade alimentar e este conhecimento pode ser utilizado no desenvolvimento de estratégias de saúde pública adequadas.

Objetivo

O objetivo principal deste estudo é avaliar a variedade alimentar e os seus fatores associados em crianças de 4 anos de idade.

Métodos

Este estudo utiliza informação da coorte Geração XXI, uma coorte de nascimentos prospetiva de base populacional que reuniu 8647 recém-nascidos e 8495 mães em todas as maternidades públicas do Porto, Portugal, entre 2005 e 2006. As crianças foram reavaliadas em 2009-2011, quando apresentavam 4 anos de idade (86% de proporção de participação). Uma amostra final de 3962 participantes de 4 anos de idade foi considerada no presente estudo por apresentarem informação completa para todas as variáveis de interesse. O consumo alimentar foi avaliado através de um questionário qualitativo de frequência alimentar relativo aos 6 meses anteriores, respondido pelo cuidador principal. Com base no *Variety Index for Toddlers,* previamente descrito na literatura, foi construído um Índice de Variedade Alimentar Saudável, considerando variedade dentro e entre cinco grupos de alimentos: 1) alimentos ricos em hidratos de carbono (incluindo batatas); 2) fruta; 3) produtos hortícolas; 4) carne, peixe e derivados; e 5) lacticínios, e o número de porções recomendado no modelo do prato alimentar dos Estados Unidos. O índice pode variar de 0 a 1, sendo que 1 representa uma maior variedade alimentar dentro e entre os grupos de alimentos. A informação sobre as características das crianças (como características ao nascimento, estilos de vida e antropometria), bem como as características da mãe e da família (dados sociodemográficos, estilos de vida, parâmetros antropométricos, estrutura familiar e número de irmãos) foram recolhidas (ou medidas) por entrevistadores treinados. As associações entre estas características e a variedade alimentar da criança foram estimadas por modelos de regressão linear generalizados

(coeficientes β, intervalos de confiança a 95%, IC95%), ajustados para o sexo da criança e idade e escolaridade maternas.

Resultados

A pontuação média no Índice de Variedade Alimentar Saudável foi de 0.78 (desvio-padrão (DP)=0.11), com um mínimo de 0.25 e um máximo de 1. A pontuação média do índice foi maior nos grupos de alimentos carne, peixe e derivados (0.88, DP=0.13) e produtos hortícolas (0.83, DP=0.21). Em análise multivariada, as crianças que aos 4 anos de idade despendiam mais de 120 minutos por dia a ver televisão e a jogar jogos eletrónicos (β=-0.012 IC95%: -0.019; -0.004), que não praticam exercício físico regular (β=-0.022 IC95%: -0.029;-0.014), que apresentavam baixo peso (em comparação com as de peso normal: β=-0.081, IC95%: -0.130;-0.032) e que nunca foram amamentadas ou que o foram por um período inferior a 4 meses (vs. ≥6 meses: β=-0.012, IC95%: -0.019;-0.005) apresentaram significativamente menor variedade alimentar. As crianças de mães menos escolarizadas (<9 vs. >12 anos: β=-0.052, IC95%: -0.061;-0.043 e 9-12 vs. >12 anos: β=-0.026, IC95%: -0.034;-0.018) e fisicamente menos ativas (β=-0.010 IC95%: -0.018;-0.001) também apresentaram menor variedade alimentar. Características familiares, como um menor número de irmãos (nenhum vs. ≥2: β=-0.023, IC95%: -0.034;-0.011) e uma estrutura familiar com pai e mãe (em comparação com uma família monoparental: β=-0.010, IC95%: -0.021;-0.001) também influenciaram negativamente a variedade alimentar aos 4 anos de idade.

Conclusão

Este estudo mostra que as crianças de 4 anos estão a consumir uma variedade de alimentos saudáveis, como é recomendado. Uma menor variedade alimentar associou-se a um elevado número de horas despendidas a ver televisão e a jogar jogos eletrónicos, à ausência de uma prática regular de exercício físico, a um baixo peso e a um período de aleitamento materno nulo ou inferior a 4 meses. Crianças de mães menos escolarizadas e fisicamente menos ativas apresentaram igualmente menor variedade alimentar. Uma estrutura familiar tradicional, sem irmãos e a viver com ambos os pais aumentou a probabilidade de ter menos variedade alimentar aos 4 anos de idade.

Investigação futura deve ser conduzida para confirmar estes resultados, uma vez que não há estudo prévio em crianças a investigar a associação da variedade alimentar com um vasto leque de características da criança e da mãe e também de estrutura familiar. Além

disso, a maioria dos estudos não avalia especificamente a variedade alimentar, mas a qualidade da alimentação, que supomos estar diretamente relacionada com a variedade alimentar.

O índice de variedade utilizado neste estudo é interessante, não só do ponto de vista da investigação, mas tem potencial para ser utilizado também em saúde pública. No entanto, em trabalhos futuros é importante testar a validade e reprodutibilidade deste índice em diferentes contextos populacionais, para ter uma compreensão mais clara da sua utilidade bem como verificar a sua capacidade discriminatória e preditiva em diversos grupos de crianças.

Palavras-chave

Variedade alimentar; crianças; estudos de coorte; comportamentos em saúde.

ABSTRACT

Introduction

Diets with higher variety are more likely to meet nutrient recommendations, but dietary variety is not always considered by diet quality indexes defined for developed countries. Population-based research with information on a wide variety of factors, assessed from a prospective approach, in pre-school aged children will enhance the identification of early life determinants of dietary variety and this knowledge may be used in the development of appropriate public health strategies.

Objective

The main objective of this study is to assess dietary variety and its associated factors in 4 years old children.

Methods

This study uses data from Generation XXI, a prospective population-based birth cohort that gathered 8647 newborns and 8495 mothers in all public maternity units from Porto, Portugal, between 2005 and 2006. The entire cohort was re-evaluated in 2009-2011, when children were at 4 years (86% of participation rate). A final sample of 3962 participants at 4 years old had complete data for the current analyses. Dietary intake was assessed by a qualitative food frequency questionnaire covering the previous 6 months, answered by the main caregiver. A Healthy Dietary Variety Index was calculated based on the Variety Index for Toddlers, considering variety within and among five food groups: 1) starchy foods (including potatoes); 2) fruit; 3) vegetables; 4) meat, fish and alternatives; and 5) dairy foods, and the number of servings as recommended in the United States food plate model. The index could range from 0 to 1, with 1 representing a higher dietary variety within and among food groups. Information on child characteristics (from birth, lifestyles and anthropometrics), as well on mothers and family (socio-demographics, lifestyles, anthropometrics, family structure and siblings) were collected (or measured) by trained researchers. The associations between these characteristics and child's dietary variety were estimated by General Linear Models (β coefficients, 95% confidence intervals, 95%CI) adjusted for child's sex, mother's age and education.

Results

The mean score of the Healthy Dietary Variety Index was 0.78 (standard deviation (SD)=0.11) with a minimum of 0.25 and a maximum of 1. The mean scores were higher for the food groups meat, fish and alternatives (0.88, SD=0.13) and vegetables (0.83, SD=0.21). In multivariate analyses, children, at 4 years old, spending more than 120 minutes per day in media screening (β=-0.012, 95%CI: -0.019;-0.004), do not practicing regular physical exercise (β=-0.022, 95%CI: -0.029;-0.014), underweight (compared with normal weight: β=-0.081, 95%CI: -0.130;-0.032) and never breastfed or breastfed for less than 4 months (compared with ≥6 months: β= -0.012, 95%CI: -0.019;-0.005) had significantly lower dietary variety. Children from less educated mothers (<9 vs. >12 years: β=-0.052, 95%CI: -0.061;-0.043 and 9-12 vs. >12 years: β=-0.026, 95%CI: -0.034;-0.018) and less physically active mothers (β=-0.010, 95%CI: -0.018;-0.001) also presented less dietary variety. Family characteristics, such as a low number of siblings (none vs. ≥2: β=-0.023, 95%CI: -0.034;-0.011) and a two-parent family structure (compared with a single-parent family: β=-0.010, 95%CI: -0.021;-0.001) also influenced negatively the dietary variety at 4 years old.

Conclusion

This study shows that 4 years old children are consuming as wide variety healthy foods as is recommended. Less dietary variety was associated with high number of media screening, no regular practice of physical exercise, underweight and never breastfeeding or breastfeeding less than 4 months. Children from less educated and less physically active mothers presented less dietary variety. A traditional family structure with no siblings and living with both parents increased the probability of having less dietary variety at 4 years of age.

Future research should confirm our results, as there is no previous study investigating in children the association of dietary variety with a wide range of both child and mother's characteristics and also the family structure. Moreover, most studies do not evaluate dietary variety in specific, but dietary quality, which we assume to be directly related with dietary variety.

The variety index used in this study is interesting not only from the research point of view, but has also potential to be used in public health. However, for future research it is important to test the validity and reliability of this index in different population settings to

have a clearer understanding of its utility alongside with its discriminatory and predictive abilities in diverse groups of children.

Keywords

Dietary variety; toddlers; Variety Index for Toddlers; cohort studies, health behaviour

INTRODUCTION

1. Importance of dietary variety since early childhood

Eating a variety of foods is essential to achieve adequate coverage of macro- and micronutrient needs (1). Dietary variety is related to the quality of the diet; diets with higher variety are more likely to meet nutritional recommendations than diets with limited variety within and among food groups (2, 3).

The concept of dietary variety is internationally recognized and the recommendation to eat a variety of foods has existed since the first edition of the Dietary Guidelines released by the United States (US) Department of Agriculture in 1980 (4). However, dietary variety is included in several recommendations specially after the International Conference on Nutrition in Rome in 1992, where a plan for action was adopted which called for the dissemination of nutrition information through sustainable food-based approaches that encourage dietary diversification through the production and consumption of micronutrient-rich foods, including appropriate traditional foods (5). Following this, in 1996, the Food and Agricultural Organization (FAO) and the World Health Organization (WHO) of the United Nations published guidelines for the development of Food-Based Dietary Guidelines that should provide simple, food-based messages, relevant to the population and easy to follow like “eat a variety of foods each day” (6).

Increasing the variety of foods across and within food groups is internationally recommended by the WHO/FAO (6) because it is thought to ensure adequate intake of essential nutrients and to promote good health (7). Therefore, public health nutritionists have historically recommended variety or diversity in dietary patterns as one means of fostering an optimal diet. The underlying concept is that no single food contains all of the necessary nutrients and that variety from dietary sources is needed to ensure a balanced diet.

Lack of dietary variety is a particular severe problem among poor populations in the developing world, where diets are mainly based on starchy staples and often include few or no animal products and only seasonal fruit and vegetables (8). For vulnerable infants and young children, the problem is particularly critical because they need energy and nutrient-dense foods to grow healthy and develop both physically and mentally (8). For these reasons, dietary diversity is now included as a specific recommendation in the WHO updated guidance for complementary feeding of breastfed children aged 6 to 23 months (9).

The nutritional quality of infant's diets in developed countries is also a public health concern as many studies have reported that infants are not eating enough fruit and vegetables and that their diets are rich in energy-dense micronutrient poor foods (10-13).

Most children tend to eat the same kinds of foods repeatedly (14). This pattern of food consumption based on a narrow set of food choices has been related to an intake of some nutrients below recommendations (15). Thus, the nutrient density of the diet given to young children is often insufficient to meet their nutrient requirements, and increase the diversity of foods provided to young children, particularly meat, poultry, fish, eggs, fruit and vegetables, is recommended to improve micronutrients intake (9).

Furthermore, a low dietary variety has also been associated with low weight and stunted growth (16, 17), future cardiovascular risk (18, 19), dyslipidemia (20) and a higher probability of developing metabolic syndrome (21).

Dietary variety established in early life seems also to be a strong predictor of later dietary variety, indicating a tracking of dietary variety over a period covering early childhood until the beginning of adulthood (1).

During the first half of the first year of life, for optimal nutrition, a single food should be consumed, i.e. milk, preferably mother's milk (22). Breast milk carries a variety of flavours determined by the foods eaten by the mother, therefore infants exposed to breast milk may show greater readiness to try new foods in the complementary feeding period and this may shape their food choices in later life (23, 24). In the case of formula feeding, most formula have similar, rather bland flavours, making milk feeding a monotonous flavour experience (1).

Around the middle of the first year, solid foods are progressively introduced in the infant´s diet (1). There is some evidence that infants weaned between 4-6 months have higher intake of fruit and vegetables in later childhood than those weaned later (25, 26) and that a greater exposure to fruit and vegetables and a higher variety in the first 2 years of life is positively associated with higher variety of fruit and vegetables at 6, 7 and 8 years of age (27). Furthermore, in an experimental study, infants were more willing to try new foods if they had been exposed to several types of vegetables rather than just one type (28).

At the end of the second year, behaviours such as food refusal, food neophobia or pickiness start to appear and the variety of food choices decreases (29). It has been shown that picky eaters have lower dietary variety and diversity scores than non-picky

eaters (30). As well, highly neophobic children have lower dietary variety and often fail to reach recommended intake levels for some nutrients (31).

After the third year of life, food behaviours tend to track over time, in particular the variety of the diet (1). In fact, dietary habits start being formed at the age of 3-4 years, and tend to become very resistant to change from the age of 11 years onward (32). In a sample of middleclass families with healthful dietary patterns, dietary variety in infancy has been associated with an increased acceptance of fruit and vegetables in later ages (27). Moreover, the consumption of fruit and vegetables during childhood is a predictor of their consumption in early adult life (33).

Thus, individual variations in dietary variety in childhood might originate from early differences in feeding experiences (1). Fortunately, the feeding behaviour is likely to adapt throughout life: repeated exposure can promote consumption of new foods at all ages (1), even in children with difficulties in accepting certain type of foods, such as vegetables (34).

2. Definition of dietary variety

Despite the well-recognized importance of dietary variety, there is still a lack of consensus about what dietary diversity or variety represents (7).

Different interpretations have been given to dietary variety. One interpretation of variety is that it represents the selection of foods from among major food groups, for example, choosing foods from among each of the Food Guide Pyramid food groups: grains, fruit, vegetables, dairy and meat (35). Another interpretation of variety is the selection of foods within food groups, for example, choosing different foods within each group of foods, such as selecting a wide variety of vegetables (35). A third interpretation relates to the type of foods in terms of health-promoting characteristics, for example, healthful variety implies a variety of recommended foods, whereas overall variety may include all types of foods, including foods high in calories, fat and sugar (36).

Additionally, dietary variety can be described as dietary variety, dietary diversity, food variety or food diversity, but the definition of these concepts is not well established. These terms often refer to the range of foods or food groups constituting the diet of a given individual, household or community and even though they imply a measure of diet quality, their use and measurement are not standardized across studies (37). In general, dietary

diversity or variety is a simple count of food items or food groups consumed by households or individuals over a certain time period (7).

Commonly, authors define the terminology used and its meaning in the introduction or when the methodology is described and its interpretation across the study depends on this (7, 38-41). In studies that used dietary diversity and food variety, generally, dietary diversity represents variety between food groups and food variety represents variety within food groups, as can be also found in the review from Arvaniti *et al* (42). However, in other studies a different meaning for dietary diversity can be found, representing the number of foods consumed across and within food groups over a specific period (7). Therefore, in this study, the term dietary variety will be preferred (instead of dietary diversity) and includes the whole range of terms that variety implies.

3. Development of diet quality indices and variety scores

Diet is a complex exposure variable, which calls for multiple approaches to summarize its effects, evaluate its determinants and examine the relationship with the disease risk (43). Dietary variety indices and scores are frequently described in the literature as a way of defining dietary patterns (42-44). This type of methodological approach will certainly not replace single nutrient or food analysis, but instead serves as a complementary approach to more traditional analysis (43). In fact, analysing food consumption as dietary patterns offers a different perspective from the traditional single nutrient approach, and may provide a comprehensive approach to disease prevention or treatment (43). It has been described that particular combinations of foods as described by dietary patterns may be more strongly related to health and disease than individual foods or nutrients (45) and that dietary preferences may be more consistent over time than consumption of individual foods (45). Moreover, studying dietary patterns could have important public health implications because the overall patterns of dietary intake might be easy for the public to interpret or translate into diets (43).

The traditional analyses in nutritional epidemiology that focus in a nutrient or few nutrients or foods have several conceptual and methodological limitations:

- People do not eat isolated nutrients (43);

- There is a high level of inter-correlation among some nutrients which makes difficult to examine their separate effects, because the degree of independent variation of the nutrients is markedly reduced when they are entered into a model simultaneously (46);
- The effect of a single nutrient may be too small to be detected, but the cumulative effects of multiple nutrients included in a dietary pattern may be sufficiently large to be detectable (47);
- Analyses based on a large number of nutrients or food items may produce statistically significant associations simply by chance (48);
- Nutrient intake is commonly associated with certain dietary patterns, and thus the single nutrient analysis may potentially be confounded by the overall effect of a dietary pattern (43).

The methodology for defining dietary patterns is relatively new compared with other techniques and is still in development (43). A number of data-reduction methods have been used; whole-of-diet analysis has taken *a priori* and *a posteriori* approaches (43, 45). Dietary patterns methods are either data driven, through principal component analysis, factor analysis or cluster analysis, among other, or determined *a priori* by the investigator, by defining dietary indices or scores (43, 45). *A priori* methods involve the assessment of food intake data against a dietary index, which is determined prior to analysis and usually reflects dietary guidelines or current nutrition knowledge. *A posterior* or data-driven techniques examine foods that are often consumed together to arrive at a dietary pattern score or to a group of individuals who consume similar types of foods (43). In general, four approaches are specially used in the literature; the first two refers to *a posteriori* methods and the latter two to *a priori* methods:

- Factor analysis – is a multivariate statistical technique, which uses information reported on food frequency questionnaires or in dietary records to identify common underlying dimension (factors or patterns) of food consumption (43).
- Cluster analysis – is another multivariate method that aggregates individuals into relatively homogeneous subgroups (clusters) with similar diets (43).
- Dietary scores – generally count the number or frequency of foods consumed that are considered by the investigator to promote health (or disease) (45).
- Dietary indices – are summary measures of the degree to which an individual's diet conforms to specific dietary recommendations (45).

In the last years, several new indices have been developed based on general national or international dietary guidelines or guidelines for the prevention of a specific disease (44). Many indices have been determined; some of them are very simple while others are much more complex. In some cases these indices add quantitative elements to qualitative aspects, while others are based on thresholds or dietary recommendations (42).

Although all these indices aim to show the overall quality of diet, and to provide a holistic tool for the ascertainment of dietary habits on human health, they often focus on specific food features, depending on the contexts and objectives of their usage (42).

The large number and the diversity of the indices proposed in the literature led Kant to classify them into three categories as a function of their determination mode: i) indices that are based on intake of nutrients; ii) indices that are based on the consumption of specific foods or food groups; iii) indices that combine both approaches (49).

In developed countries, indices are often composed of several dimensions such as nutrient adequacy, dietary diversity, proportionality (more of some foods groups and less of others) and moderation (limiting the intake of food constitutions to excess risk) (50). Some of the most commonly indices or scores used are the Healthy Eating Index, the Canadian Healthy Eating Index, the Australian Healthy Eating Index, the Alternative Healthy Eating Index, the Dietary Guideline Index, the Diet Quality Index, the Dietary Quality Score, the Diet Quality Index Revised, the Diet Quality Index-International, the Healthy Food Index, the Heart Disease Prevention Eating Index, the Dietary Guidelines Index, the Mediterranean Diet Quality Index and the Mediterranean Score (42, 44).The most common measures that include variety as a component are the Diet Quality Index Revised and the Healthy Eating Index (51).

Various scores have been also developed based on the concept of food variety or diversity (44). The two scores more often described seem to be the Dietary Diversity Score, a count of food groups (52), and the Food Variety Score, a simple count of food items (52). Both types of scores have been used in several studies, trying to answer the question whether it is better to determine scores from food items (Food Variety Score) or from food groups (Dietary Diversity Score) (42).

3.1. Dietary variety indices among children

The assessment of children's diets has traditionally focused on energy and the nutrient composition of the diet (14, 15) rather than on the variety of dietary choices or the patterns of food selection (51). However, food-based analyses of the total diet are becoming increasingly more prominent in nutrition research, and the use of diet quality indices in paediatric populations is increasing internationally in highly diverse populations (53).

Two reviews had explored diet quality measures used in the paediatric population from developed countries only. The review conducted by Smithers et al. concluded that the use and application of diet quality indices, especially in regard to weight status in developed nations, had not been fully explored (54). The review by Lazarou & Newby also concluded that further research is required to gain a better understanding of paediatric diet quality and health-related outcomes (55). Because of that, Marshall et al. developed a review that summarizes all paediatric diet quality indices and scores published up to October 2013, that expands the information presented in these reviews by incorporating populations from developing countries and additional studies published after 2010, as well as providing a more systematic summary of the diet quality indices' attributes and uses (53).

According to data presented in this review, continental trends were observed in the type of scoring method used in the paediatric population. Diet quality indices developed in Europe were predominantly food-based, and include a number of simpler dietary variety or dietary diversity scores. Alternatively, North American derived dietary quality indices were largely food- and nutrient-based scores requiring nutrient analysis for calculation. In addition, the dietary methods and scoring for dietary quality indices in developing nations were found to be more simplistic compared to developed nations overall (53). This may be because application in these countries needs to be less time and resource intensive as a result of the fieldwork settings, and applicable to population where food is often shared communally (52).

Although an index is often developed for a specific population, many have been used in diverse populations, with or without modifications (53). For example, several modifications to the Healthy Eating Index subscales were made for culturally diverse populations and specific geographic locations, including Brazil (56, 57), Spain (58) and for Native Hawaiians in the USA (59). In addition, many of the indices have been updated or used as modified versions, for example the Diet Quality Index-International (DQI-I) (60) and the Mediterranean DQI-I (61) were adapted from the original Diet Quality Index (62), whereas

the Revised Children's Diet Quality Index (63) was updated from the Children´s Diet Quality Index (64). Based on the Marshall et al. review (53), table 1 summarizes the diet quality indices or scores that have been designed for use in paediatric populations.

Table 1 – Diet quality indices or scores, designed for use in paediatric populations, based on Marshall et al. review (53).

Diet Quality Indices or Scores	Country of origin	Age group
Healthy Eating Index (HEI)	USA*	>=2 years
Healthy Eating Index – 1995 (HEI-2005)	USA	2-18 years
Canadian Healthy Eating Index (HEI-C)	Canada	>= 3 years
Canadian Healthy Eating Index – 2009 (HEIC-2009)	Canada	>= 3 years
Children's Diet Quality Index (C-DQI)	USA	2-5 years
Revised Children's Diet Quality Index (RC-DQI)	USA	2-18 years
Variety Index for Toddlers (VIT)	**USA**	**Toddlers**
Nutrient Rich Foods (NRF)	USA	4 years - adult
Food Variety (FV) Score	USA	Children
Diet Quality Index for Preschool Children (DQI-CH)	Belgium	2-6 years
Complementary Feeding Utility Index (CFUI)	England	Infants and toddlers
Healthy Nutrition Score for Kids and Youth (HuSKY)	Germany	3-17 years
Indicator Food Index (IFI)	Germany	Children and adolescents
Diet Quality Score	Germany	Children
Preschool Diet-Lifestyle Index (PDL-Index)	Greece	2-5 years
Diet Quality Score	Scotland	2-5 years
Australian Child and Adolescent Recommended Food Score (ACARFS)	Australia	6-14 years
Core Food Variety Score (CFVS)	Australia	Toddlers
Fruit and Vegetable Variety Score (FVVS)	Australia	Toddlers
Obesity Protective Dietary Index (OPDI)	Australia	Infants
Dietary Diversity Score (DDS)	Philippines	Non-breastfeed infants
Dietary Diversity Score 10 g (DDS 10 g)	Philippines	Non-breastfeed infants
Food Variety Score (FVS)	Cambodia	Infants and toddlers
Dietary Diversity Score (DDS)	Bangladesh	< 5 years
Dietary Diversity Score (DDS)	Iran	>= 10 years
Infants and Child Feeding Index (ICFI)	Design in USA for use in Latin American	6-36 months
Dietary Diversity Indicator	Design in USA for use in Southeast Asian, Latin America and Africa	Infants
Food Diversity Index (FDI)	Bolivia	Pediatric and adults
Traditional Food Diversity Score (TFDS)	Peru	Pediatric and adults
1 and 3 day Food Variety Score (FVS)	Guatemala	Infants
USAID Dietary Diversity Score (DDS)	Guatemala	Infants
Cooking Pot Dietary Diversity Score (DDS)	Guatemala	Infants
INCAP Papers Dietary Diversity Score (DDS)	Guatemala	Infants

Table 1. Continuation – Diet quality indices or scores, designed for use in paediatric populations, based on Marshall et al. review (53).

Diet Quality Indices or Scores	Country of origin	Age group
Dietary Diversity Score (DDS8)	Madagascar	Infants aged >=6 months
Dietary Diversity Score (DDS8-R)	Madagascar	Infants aged >=6 months
Dietary Diversity Score (DDS7)	Madagascar	Infants aged >=6 months
Dietary Diversity Score (DDS7-R)	Madagascar	Infants aged >=6 months
Dietary Diversity Score (DDS)	South Africa	Infants aged >=6 months
Dietary Diversity Score (DDS)	Design in Norway to be use in economically poor countries, such as Mali	13-58 months
Food Variety Score (FVS)	Design in Norway to be use in economically poor countries	>=13 months to adults
Dietary Diversity Score (DDS)	South Africa	1-8 years
Food Variety Score (FVS)	South Africa	1-8 years
Dietary Diversity Index (DDI)	Senegal	Infants and toddlers
Food Variety Index (FVI)	Senegal	Infants and toddlers

*USA: United States of America

From the 80 indices or scores presented in this review (53), 44 were designed to be used in children. From these 44 studies, 20 were created to be used in paediatric populations from developed countries and 24 from developing countries. In developing countries, only one index was not exclusively designed to represent dietary variety but included dietary variety as one item of the diet quality index (65). In developed countries, 4 indices are specific dietary variety indices and 16 are dietary quality indices (53). From these 16 dietary quality indices, 5 included dietary variety (66-69).

Cox et al. developed a variety index specific to toddlers, the Variety Index for Toddlers (VIT) (70). This index results from an effort to create a variety index as a component of the Healthy Eating Index (50). The VIT assesses variety within and among food groups based on the number of servings from the food groups in the Food Guide Pyramid and also reflects dietary adequacy (70). The VIT can be potentially adapted to other age groups and populations by adjusting the serving sizes and the number of recommended servings per day (70).

Many potential applications exist for the VIT, as reported by Cox, et al.:

- In nutrition education as a tool for teaching nutrition students a more concrete concept of variety diet;
- In research for tracking changes in dietary variety over time or for comparison with growth parameters or socioeconomic factors;

- In clinical and community settings for teaching the importance of dietary variety to individuals;
- In industry for tracking market trends from the component food group scores or for measuring the impact of certain foods on the overall diet (70).

Dietary indices are useful tools for dietary assessment, but prospective and intervention research in diverse populations and additional validation studies are needed to strengthen the utility of these tools in understanding dietary quality in children and in showing associations with meaningful health outcomes (55).

3.2. Strengths and limitations of dietary indices used in children

According to the Lazarou et al. review (55) dietary indices used in children have some strengths and limitations. The four overall strengths include the following: 1) the ability to translate successfully a set of dietary guidelines or evidence into a single, comprehensible assessment tool that reflects adherence to a healthful diet prototype; 2) indices are associated with a wide variety of dietary characteristics; 3) indices are associated with important socio-demographic characteristics; and 4) indices are associated with some meaningful health outcomes (55).

On the other hand, the limitations of dietary quality indices are: 1) there is a large variety of indices used in the literature, with relatively few studies within any given age group; 2) the quality of the primary dietary assessment tools used to driven the dietary indices (e.g. food frequency questionnaire, food record) varies considerably, making comparisons across studies difficult; 3) most results are from descriptive analyses and most analytic studies showed weak associations, with limited if any adjustment for potential confounders; 4) only a handful of studies compared different indices to determine which was better associated with a given outcome, thus, it is unclear which indices are better than others; 5) only two validation studies were performed (55).

The application of more robust methods to create indices and more rigorous methods to measure discriminative power may increase the content validity of those tools (55). Those methods may include: 1) applying specific weights to each component scale of the index on the basis of relative importance (71-73); 2) grouping index components according to the domain of the dietary behaviour they assess (e.g. diet composition, beliefs, behaviours)

(74); 3) conducting proper statistical tests to evaluate the discriminating characteristics and abilities of the index, such as sensitivity, specificity, c-statistic values, positive/negative predictive values, and others (55); and 4) performing additional tests beyond multivariate regression analysis to reveal any potential heterogeneity in the index performance (74) including latent class analysis (74, 75), structural equation modelling (76) and data mining (77).

In addition, it is necessary to validate a study, use a superior method for comparison rather than relying upon the same dietary assessment method, as it has been done in the vast majority of the studies in the Lazarou et al. review (55). Optimally, validation of dietary assessment tools should be evaluated with methods having uncorrelated errors, ideally nutritional biomarkers and/or a more accurate, gold standard method of self-report dietary assessment such as food records (78, 79). Comparison with a superior dietary assessment method, such as multiple days of food records, may be more feasible and would also provide greater confidence in the soundness of these indices (55).

4. Factors associated with dietary variety

An examination of all reported paediatric diet quality indices, including those in both developed and developing nations, their association with health-related outcomes, and a thorough exploration of factors associated with diet quality in children remains incomplete (53).

According to a systematic review, diet quality indices in children and adolescents have been frequently associated with weight status, followed by height/length (53). In developing nations, where a risk of under-nutrition rather than over-nutrition is the major concern, several studies have been consistently associated dietary variety with a better nutritional status and growth (8, 16, 41, 80-82) as well as a good indicator of nutritional adequacy (17, 52, 83, 84). However, associations with weight status in populations at risk of over-nutrition have been inconsistent with studies finding both negative and positive associations (53).

In the majority of the studies in developed countries, higher diet quality scores were associated with more favourable nutrient and food intake, more healthful dietary behaviours, lower chronic diseases risk factors and fewer asthma-related conditions among children (55). In addition, significant associations between diet quality indices and

various socio-demographic variables, including sex, age, race/ethnicity, income, parental education, socio-economic status, place of living and marital status of parents were reported previously (85-92). Some of these associations were also find in developing countries especially with maternal education (82, 93, 94) and number of children in the family (93). The description of some of these and other studies are described below.

In children and adolescents, a better overall dietary quality has been found among girls than boys (85, 86).

In a study among 4 to 16 years old children from a developed country, dietary quality in children was positively associated with household income (91). However, it was not found a relationship between dietary variety and food insecurity or insufficiency in a cross-sectional study in children from the US (87). In developing countries, it is often suggested that the household-level dietary diversity is strongly positively associated with household per capita income and energy availability, suggesting that dietary diversity could be a useful indicator of food security (7, 41). However, in mother-child from 6-24 months in Bangladesh, Vietnam and Ethiopia, food security and socioeconomic status were not significantly associated with dietary diversity, including the maternal dietary diversity in the model (93).

A better maternal education has been also associated with a better dietary diversity in children in developed (88) and developing countries (82, 93, 94) as well as higher maternal age and education with a healthier dietary pattern of toddlers and preschool children from developed countries (89, 90).

Another factor that has been related with dietary diversity in developed countries is the duration of breastfeeding. A positive modest association between breastfeeding duration and food variety was found in 2 year old children, independently of maternal demographic characteristics known to predict dietary quality in children (88). In addition, fruit variety in the school-aged child was predicted by breastfeeding duration in a North American study (27).

Furthermore, other factors have been associated with dietary quality in developed countries. In a Norwegian study, mothers who were daily smokers and had higher Body Mass Index (BMI) were more likely to have children with an ‘unhealthy’ diet (89). In addition, in a study developed in Finland, a lower dietary quality was associated with smoking during pregnancy among 6-years-old children (95).

Factors related with family characteristics, such as the number of siblings and the family structure have been also related with diet quality. Dietary variety was inversely associated

with the number and presence of older siblings (88), the same kind of association was found with diet quality (90, 91). In developing countries an association of dietary variety with a lower number of children in the family were also found (93). A family structure composed by two parents (91, 92) was associated with better diet quality.

Lifestyles characteristics, such as sedentary behaviours in children, appear to be associated with elements of a less healthy diet, as reported in a systematic review (96). Eating while watching TV negatively affected the consumption of fruits and vegetables and overall diet quality in a study with children aged 10-11 years old (97). In addition, lower TV-viewing time was associated with higher scores in the Healthy Heating Index-2005 (i.e., healthier diet) in children and adults (98). Dietary quality was also associated with physical activity practice (99, 100).

Overall, although some studies have been conducted to examine factors responsible for diet quality, just one examined factors responsible for dietary diversity in developed countries (88). Population-based research with information on a wide variety of factors, assessed from a prospective approach, in preschool-aged children will enhance the identification of early life determinants of dietary variety and this knowledge may be used in the development of appropriate public health strategies.

AIMS

The aims of this study are:

- To assess dietary variety in preschool-aged children, by defining a Healthy Dietary Variety Index based on the Variety Index for Toddlers (VIT).
- To evaluate the association of child, mother and family characteristics with less dietary variety in 4 years old children.

MANUSCRIPT

Association of child and family characteristics with a healthy dietary variety index in 4 years old children

[To be submitted]

Association of child and family characteristics with a healthy dietary variety index in 4 years old children

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ABSTRACT

Introduction: Diets with higher variety are more likely to meet nutrient recommendations, but dietary variety is not always considered by diet quality indexes defined for developed countries.

Objective: The main objective of this study is to assess dietary variety and its associated factors in 4 years old children.

Methods: This study uses data from Generation XXI, a prospective population-based birth cohort that gathered 8647 newborns and 8495 mothers in all public maternity units from Porto, Portugal, between 2005 and 2006. At 4 years, 86% of children were re-evaluated. Data were collected by trained researchers in face-to-face interviews. Dietary intake was assessed by a qualitative food frequency questionnaire covering the previous 6 months, answered by the main caregiver. A Healthy Dietary Variety Index was calculated based on the Variety Index for Toddlers, considering variety within and among five food groups, and associated with mother, child and family characteristics by General Linear Models (β coefficients, 95% confidence intervals, 95%CI) adjusted for child's sex, mother's age and education. A final sample of 3962 participants at 4 years old had complete data for the current analyses.

Results: The mean score of the Healthy Dietary Variety Index was 0.78 (standard deviation (SD)=0.11) with a minimum of 0.25 and a maximum of 1. In multivariate analyses, children, at 4 years old, spending more than 120 minutes per day in media screening (β=-0.012, 95%CI: -0.019;-0.004), do not practicing regular physical exercise (β=-0.022, 95%CI: -0.029;-0.014), underweight (compared with normal weight: β=-0.081, 95%CI: -0.130;-0.032) and never breastfed or breastfed for less than 4 months (compared with ≥6 months: β= -0.012, 95%CI: -0.019;-0.005) had significantly lower dietary variety. Children from less educated mothers (<9 vs. >12 years: β=-0.052, 95%CI: -0.061;-0.043 and 9-12 vs. >12 years: β=-0.026, 95%CI: -0.034;-0.018) and less physically active mothers (β=-0.010, 95%CI: -0.018;-0.001) also presented less dietary variety. Family characteristics, such as a low number of siblings (none vs. ≥2: β=-0.023, 95%CI: -0.034;-0.011) and a two-parent family structure (compared with a single-parent family: β=-0.010, 95%CI: -0.021;-0.001) also influenced negatively the dietary variety at 4 years old.

Conclusion: This study shows that 4 years old children are consuming as wide variety healthy foods as is recommended. Less dietary variety was associated with high number of media screening, no regular practice of physical exercise, underweight and never

breastfeeding or breastfeeding for less than 4 months. Children from less educated and less physically active mothers presented less dietary variety. A traditional family structure with no siblings and living with both parents increased the probability of having less dietary variety at 4 years of age.

Keywords: Dietary variety; toddlers; Variety Index for Toddlers; cohort studies; health behaviour

INTRODUCTION

Eating a variety of foods is essential to achieve adequate coverage of macro- and micronutrient needs (1). Dietary variety is related to the quality of the diet; diets with higher variety are more likely to meet nutrient recommendations than diets with limited variety within and among food groups (2, 3).

Individual variations in dietary variety during childhood might originate from differences in early feeding experiences (4). Dietary variety established in early life seems also to be a strong predictor of later dietary variety, indicating a tracking of dietary variety over a period covering early childhood until the beginning of adulthood (1). Fortunately, the feeding behaviour is likely to adapt throughout life: repeated exposure can promote the consumption of new foods at all ages and dietary variety established in early life seems to track over a period covering early childhood until the beginning of adulthood (1).

The nutritional quality of infant's diets is a public health concern as many studies have reported that infants are not eating enough fruit and vegetables (5) and that their diets are rich in energy-dense micronutrient poor foods (6-9). The assessment of diet during childhood has traditionally focused on the role of specific nutrients or foods (10), rather than on the variety of dietary choices or the patterns of food selection (11). However, food-based analyses of the total diet effects are becoming increasingly more prominent in nutrition research (12) and the use of dietary quality indices and scores in the paediatric population is increasing internationally in different population settings (13). In a review, Marshall *et al.* summarizes dietary quality indices and scores, their attributes and uses (13). According to this review, only a quarter of these indices were designed to be used in children from developed countries. In fact, experience from developed countries in measuring dietary variety prospers, but measurement approaches, indicators and validation methods differ widely between studies (14). Cox *et al.* developed a variety index based on the United States (US) Food Guide Pyramid that provides a numeric description of dietary variety specific to toddlers, indicative of dietary adequacy, and many potential applications have been described for its use (15).

Significant associations between diet quality indices and various socio-demographic variables, including sex, age, race/ethnicity, income, parental education, socio-economic status, place of living and marital status of parents were reported previously in developed countries (16-19). Additionally, other factors such as longer breastfeeding duration (4, 16); family characteristics such as a lower number of siblings (16, 18, 19), and a family

structure of two parents (18); child's lifestyles, such as lower TV-viewing time (20, 21) and physical activity practice (22, 23) have been associated with high diet quality in children. On the other hand, a better diet quality in children was inversely associated with Body Mass Index (BMI) of the mother (17) and smoking during pregnancy (24).

Overall, although some studies have been conducted to examine factors responsible for diet quality in children, just one examined factors responsible for food variety in developed countries (16). Population-based research with information on a wide variety of factors, assessed from a prospective approach, in pre-school aged children will enhance the identification of early life determinants of dietary variety and this knowledge may be used in the development of appropriate public health strategies.

The main objective of this study is to assess dietary variety and its associated factors in 4 years old children.

PARTICIPANTS AND METHODS

This study uses data from Generation XXI, a prospective population-based birth cohort, previously described elsewhere (25). Generation XXI gathered newborns and their mothers, recruited in all public maternity units from Porto, Portugal, between April 2005 and August 2006. A total of 8647 children and 8495 mothers were enrolled at baseline. Of the invited mothers, 91.4% agreed to participate. During the first 24 to 72 hours after delivery, trained interviewers collected data on demographic and social conditions, lifestyles, medical history and prenatal care. Birth data was retrieved from medical records by trained researchers.

The entire cohort was re-evaluated between April 2009 and April 2011, when children were at 4 years, and 86% of all children were re-evaluated (70% by face-to-face interviews). Data on demographics and social conditions, lifestyles, sleeping habits and medical care were collected by trained interviewers. Anthropometrics (weight, height and waist circumference) and body composition, by tetra-polar bioelectric impedance, were also measured. Parents provided reports on children's dietary intake (3-day food records and a list of food frequencies of consumption).

For the present analysis, only one of a pair of twins was randomly included. Participants, who had no information for the Healthy Dietary Variety Index and the main variables of interest, were excluded. Thus, the final sample included 3962 participants. We

compared characteristics of the present study sample (n=3962) with the remaining cohort (n=4685) at baseline, and no significant differences were found for child's sex (51.5% vs. 50.6% of boys, p=0.390). However, significant differences were found for maternal age and education. Mothers in this study were slightly older (mean=29.8 years; standard deviation (SD)=5.25 vs. mean=28.3; SD=5.78, p<0.001) and more educated (mean=11.2 years; SD=4.29 vs. mean=9.8 years; SD=4.14, p<0.001) than mothers in the remaining cohort. The Cohen's effect size values were lower than 0.35, suggesting that the magnitude of the differences was not high (i.e. differences were at most part due to the large sample size than due to large differences between participant's characteristics) (26).

The study was conducted according to the principles of the Declaration of Helsinki and all procedures were approved by the Ethics Committee of the Hospital de São João and the Portuguese Authority of Data Protection. Parents or legal tutors of each participant signed a consent form.

Dietary data (the Healthy Dietary Variety Index)

The main caregivers (usually mothers) were asked to answer a 35-item food frequency questionnaire (FFQ) on child's diet over the previous 6 months. The FFQ includes 3 items of starchy foods, 1 item of fruits, 3 items of vegetables, 5 items of meat, fish and alternatives, 5 items of dairy foods, 6 items of sweets/candy foods, 3 items of energy-dense foods, 1 item of butter/margarine, 3 items of non-sweet beverages and 5 items of sweet beverages. Nine response categories were available, varying between never and 4 or more times per day.

In a sub-sample of approximately 2500 children, 3-day food records were also completed, and correlations between key food groups measured by the FFQ and food diaries were calculated to assess the validity of the FFQ. Pearson's coefficients showed a weak-to-moderate positive correlation for most food groups (results not showed).

In this study, a Healthy Dietary Variety Index was calculated based on the Variety Index for Toddlers (VIT) developed by Cox et al (15). To develop the Healthy Dietary Variety Index, the FFQ data, the food groups and the number of servings as recommended in the food plate model (former pyramid model) based on healthy eating guidelines promoted by the U.S. Department of Agriculture were used. To calculate this index the following steps were considered:

i) Calculation of the daily number of servings of each food item based in the frequencies obtained in the FFQ.

ii) Allocation of the food items to one of five food groups: 1) starchy foods (including potatoes); 2) fruit; 3) vegetables; 4) meat, fish and alternatives; and 5) dairy foods.

iii) Application of truncations to ensure variety within food groups. A contribution of a food item was truncated at 33% within each food group. Foods within a food group which are extremely similar (e.g. yoghurts without sugar and sweetened yoghurts) were grouped together and counted as a single food so that they do not contribute more than 33%. The number of servings for each food group was complete after the groupings and truncations were applied. It was not possible to assess variety within fruit and vegetables due to limited questions of the FFQ. For fruit and vegetables, the index instead reflects whether or not the children ate the recommended number of servings.

iv) Calculation of the food group index by dividing the total number of servings by the recommended number of servings per day for each food group. The following recommended number of servings was used: starchy foods = 7, fruit = 2, vegetables = 3, meat, fish and alternatives = 2 and dairy foods = 3.

v) Application of another truncation to ensure variety between the food groups. Each food group score was truncated at 1.00 (e.g. if a child ate a serving of 3 different types of meat, fish and alternatives, each day this is divided by 2 thus giving a potential score of 1.5 which is truncated to 1.00). This means that a high intake of one food group cannot compensate mathematically for a low intake in another food group, thus ensuring variety across the food groups.

vi) Calculation of the final Healthy Dietary Variety Index. It is the sum of the five group indices divided by 5; the index could range from 0 to 1, with 1 representing a higher dietary variety within and among food groups.

Child, mother and family characteristics

Birth characteristics were retrieved from medical records, such as the type of delivery (vaginal or caesarean), gestational age and birth weight. Weight for gestational age were defined according to sex-specific population-based Kramer growth standards (27); small for gestational age and large for gestational age were defined as below the 10th and above the 90th percentile, respectively; appropriate for gestational age was deemed to be within these thresholds. These standards refer only for single births.

Child’s characteristics, such as child´s sex was collected at baseline. Other characteristics such as physical activity (defined as the regular practice of physical exercise), the number of media screening hours (subdivided in less or 120 minutes or

more per day) and breastfeeding duration (recoded into never or less than 4 months, between 4 and 5 months, 6 months or more) were assessed based on information collected at 4 years. Anthropometric data on weight and height were also obtained by trained researchers. Weight was measured in light clothing and without shoes using a digital scale and was recorded to the nearest 0·1 kg. Height was measured as the distance from the top of the head to the bottom of the feet without shoes using a fixed stadiometer to the nearest 0·1 cm. The BMI was calculated as the weight (kg) over the squared height (m). Each child was then classified according to the age- and sex-specific BMI reference z-scores developed by the World Health Organization (28), and recoded into underweight or normal weight (BMI <2 SD) and overweight/obese (BMI $\geq$2 SD).

Mother's characteristics under evaluation in the present study, gathered at baseline, include maternal age, education, smoking during pregnancy (ever and never smoker) and self-reported BMI before pregnancy. Maternal anthropometrics were also measured at 4 years-old, including height, weight and waist circumference. Maternal BMI was calculated according to the formula previously described and classified according to the WHO criteria into underweight (BMI<19.5 kg/m^2), normal weight (BMI 19.5-24.9 kg/m^2), overweight (BMI 25.0-29.9 kg/m^2) and obese (BMI ≥30.0 kg/m^2) (29). Maternal waist circumference was measured midway between the lower limit of the rib cage and the iliac crest, to the nearest centimetre and using a flexible and non-distensible tape.The waist circumference was categorized into low risk (<80 cm), increased risk (80.0 to 87.9 cm) and high risk (≥88.0 cm), according to the World Health Organization criteria (30). Mother's lifestyles, such as physical activity was assessed based on information collected at the 4 years old evaluation.

Family characteristics, such as the number of siblings (recoded into none, one, two or more) and family structure (living with both parents, with single parent or having other family structure) were also asked at 4 years old.

Statistical analysis

Descriptive statistics (mean and the respective standard deviation (SD)) were presented and General Linear Models (β coefficients, 95% confidence intervals (95%CI)) were performed to estimate the association between child, mother and family characteristics and the Healthy Dietary Variety Index.

At multivariate analysis, three models were considered: model 1 was adjusted for child's sex, and mother's age and education; model 2 was adjusted for variables from

model 1 plus media screening, breastfeeding duration and number of siblings; and model 3 was adjusted for variables from model 2 plus child's z-score BMI at 4 years.

An interaction of the child's sex in these associations was studied, by conducting stratified analysis, but no significant interaction was found; thus, results are reported for both sexes together.

A significance level of 5% was set. SPSS Statistics 21.0 (SPSS Inc., Chicago, IL, USA) was used to perform all the statistical analyses.

RESULTS

The distribution of the Healthy Dietary Variety Index and its individual food groups is reported in Table 1. The final index could range between 0 and 1, with 1 representing a higher variety and adequacy. In this sample, the mean score of the Healthy Dietary Variety Index was 0.78 (SD=0.11) with a minimum of 0.25 and a maximum of 1. The mean scores were higher for the food groups meat, fish and alternatives (mean=0.88, SD=0.13) and vegetables (mean=0.83, SD=0.21) and lower for the starchy foods (mean=0.68, SD=0.17) and fruit (mean=0.77, SD=0.30).

Child, mother and family characteristics are described in Table 2. Just over half of child are male (51.5%) and the majority was born from a vaginal delivery (61.1%), with an adequate weight for gestational age (82.0%). At 4 years old, most children spent more than 120 minutes per day in media screening (71.3%), practiced regular physical exercise (68.3%), presented a normal weight (68.1%) and were breastfed for 6 or more months (54.3%). The majority of mothers had 25 to 34 years-old at baseline (66.1%), 9 to 12 years of education (42.3%), never smoked during pregnancy (79.9%), had a normal weight before pregnancy (65.5%) and at 4 years of age of their sons (46.5%), and also had a waist circumference below 80 cm (42.4%). Approximately 81% of mothers did not practice regular physical exercise (80.9%) at 4 years old of children. Family characteristics show that most children did not have brothers (46.6%) and lived with both parents (87.2%) at 4 years old.

The univariate associations of the child, mother and family characteristics with the Healthy Dietary Variety Index are also presented in Table 2. A significantly lower score in the Healthy Dietary Variety Index was observed in 4 years old children that spent more than 120 minutes per day in media screening (β=-0.017, 95%CI:-0.025;-0.010), do not

practicing regular physical exercise (β=-0.028, 95%CI:-0.036;-0.021), underweight (compared with normal weight: β=-0.085, 95%CI:-0.134;-0.035) and never breastfed or breastfed for less than 4 months (compared with ≥6 months: β=-0.014; 95%CI:-0.022;-0.007). In addition, children from younger mothers (<25 vs. ≥35 years: β=-0.014, 95%CI: -0.025;-0.002), less educated (<9 vs. >12 years: β=-0.052, 95%CI: -0.060;-0.043), overweight (compared with normal weight: β=-0.009, 95%CI: -0.017;-0.002) or obese at 4 years of child's age (β=-0.010, 95%CI: -0.019;-0.001) and with a waist circumference higher than 88 cm (compared with < 80 cm: β=-0.011, 95%CI: -0.019;-0.003) also presented significantly lower scores in the Healthy Dietary Variety Index. Those mothers who did not practice regular physical exercise were also associated with less child's dietary variety (β=-0.018, 95%CI: -0.027;-0.010). Less dietary variety was also related with not having siblings (none vs. ≥2: β=-0.013, 95%CI: -0.024;-0.002). Child's characteristics at birth, mother's smoking during pregnancy, mother's BMI before pregnancy and the family structure were not significantly associated with the Healthy Dietary Variety Index.

The multivariate analyses are presented in Table 3. Adjustments considered in model 1 (child's sex and mother's age and education) show to be the main confounders of the reported associations, and thus model 1 was considered as the final model. According to this, children spent more than 120 minutes per day in media screening (β=-0.012, 95%CI: -0.019;-0.004), do not practicing regular physical exercise (β=-0.022, 95%CI: -0.029;-0.014), underweight at 4 years (compared with normal weight: β=-0.081, 95%CI: -0.130;-0.032) and never breastfed or breastfed for less than 4 months (compared with ≥6 months: β= -0.012, 95%CI: -0.019;-0.005) had significantly lower scores in the Healthy Dietary Variety Index. Children from less educated mothers (<9 vs. >12 years: β=-0.052, 95%CI: -0.061;-0.043 and 9-12 vs. >12 years: β=-0.026, 95%CI: -0.034;-0.018) and less physically active mothers (β=-0.010, 95%CI: -0.018;-0.001) also presented less dietary variety. Family characteristics, such as a low number of siblings (none vs. ≥2: β=-0.023, 95%CI: -0.034;-0.011) and a two-parent family structure (compared with a single-parent family: β=-0.010, 95%CI: -0.021;-0.001) also influenced negatively the dietary variety at 4 years old.

DISCUSSION

This study investigated the dietary variety in 4 years old children, with a modified version of a previous dietary variety index, assessing dietary variety within and among food groups (15). The results show that children are consuming as wide variety healthy foods as is recommended (the mean score was 0.78 from a maximum of 1.00), and just in the group of starchy foods none of the children reached the recommended score of 1.00.

Results observed in this study for the total mean score are slightly lower compared with the mean score reported in the original study of Cox *et al.* (mean score of 0.80) (15), but higher when compared with other studies, such as the one from Powers and co-workers (mean score of 0.70 was reported) (31). However, these two studies used data from 3-day food records, had a smaller sample and were applied in children with 1 to 3 years old (15, 31), which could hamper straight comparison with our study.

If we analyse the individual contribution of food groups for the total Healthy Dietary Variety Index, we can observe that the food groups of vegetables (mean score of 0.83) and meat, fish and alternatives (mean score of 0.88) had higher scores compared with the same two studied cited before (0.73 (15) and 0.26 (31) for vegetables and 0.74 (15) and 0.73 (31) for meat, fish and alternatives). A higher score for vegetables was not expected, because previous studies have reported that infants are not eating enough fruit and vegetables (5-9). However, countries in south Europe, such as Portugal, seem to follow a better nutritional diet than other countries (32), and we should keep in mind that in the present study, for fruit and vegetables, we are only analysing dietary adequacy and not variety (we have only 3 items in this food group). The higher score in meat, fish and alternatives group can be also related with the traditional diet followed in Portugal, because the Mediterranean dietary pattern includes consumption of fish and shellfish, white meat and eggs (33).

Furthermore, this study aimed to examine the association of child, mother and family characteristics with dietary variety. We found that children of 4 years old who spend more than 120 minutes per day in media screening, do not practicing regular physical exercise, underweight and never breastfed or breastfed for less than 4 months had less dietary variety. Children from less educated mothers and less physically active mothers also presented less dietary variety. Family structure characteristics, such as do not having sibling and live with both parents increased the probability of having less dietary variety at 4 years of age.

To the best of the authors' knowledge, no previous study has investigated in children the association of dietary variety with a wide range of both child and mother's characteristics and also the family structure. Because of that, some results are difficult to compare. Moreover, some studies do not evaluate dietary variety in specific, but dietary quality, which we assume to be directly related with dietary variety (34, 35).

Children´s lifestyles, such as sedentary behaviours, represented in our study by spending more than 120 minutes per day in media screening or do not practising regular physical exercise, have been related with dietary quality, using other indices, such as the Healthy Eating Index-2005 and similar results were reported: a lower TV-viewing was associated with a higher Healthy Eating Index-2005 that represents a healthier diet in children and adults (20). Another index, the Healthy Eating Index-2010 was also related with physical activity, but no significant associations were found (36). However, none of these scores include variety. Another study developed in Greece, in children with 2 to 5 years old used the Healthy Eating Index, that include variety, and a low score was associated with low levels of physical activity (22). In another study, that also used an index including variety to describe dietary quality, the Canadian version of Healthy Eating Index, the positive association between diet quality and some aspects of physical activity suggests possible clustering of healthy behaviours and the authors suggest in future research, to test the potential benefits of promoting one health behaviour (e.g. healthy eating) with another (e.g. physical activity) (23).

In the present study, underweight children presented less dietary variety than normal weight children, like in others studies previously described in the literature (34, 37-39). However, the reasons for study this association can be different because these studies were mostly designed in developing countries where the major concern is the nutritional status of children. Furthermore, the scores used in these studies were the Food Variety Score (37), the Dietary Variety Score (39) or both (34, 38) that do not include variety within and among food groups and dietary adequacy, as in our study. The reported association could, at some extent, be explained by certain feeding behaviours, such as picky eating (the consumption of an insufficient amount or an inadequate variety of foods through rejection of food items (40, 41)) and food neophobia (frequently adopted by underweight children), that have been associated with less dietary variety in young children (42).

According to other studies from developed countries, the breastfeeding duration is positively associated with dietary variety (4, 16). This finding is consistent with the notion that infants' experiences with breast milk enhance their exposure and thus their

acceptance of a variety of flavours (43). However, in these studies, dietary variety was represented by scores specifically created by their authors to evaluate fruit and vegetables variety, and the studies were applied in a sample of 2 years old children (16) or school aged-children (4).

In our study, mothers less educated have children with less dietary variety and this association was found in both developing (37, 44, 45) and developed (16) countries, even with differences in the measurement of dietary variety. In fact, maternal education seems to be a strong predictor of dietary variety and a main confounder of most of the associations reported in the present study.

Contrary to what was expected, in our study, do not having siblings was related with less dietary variety. In a previous study, it was found that a higher number of children in the family were associated with lower dietary diversity in children with 6-24 months from Bangladesh and Vietnam (44). In another study developed in Australia including children and adolescents between 4 and 16 years old, and using an index that included variety (the Dietary Guideline Index for Children and Adolescents), the authors found that after adjustment for child's age, gender, BMI, energy intake and socio-demographic characteristics, the number of children in the household was negatively associated with the score (19). In our study, children had 4 years old and at that age, picky eating can increase significantly and, as previously reported, having siblings protects against the development of picky eating at that ages (46).

Living with both parents in our study was also related with less dietary variety. Again, this result was not expected because it has been previously described in an Australian study in children aged between 4 and 16 years old that single-parent families were negatively associated with the Dietary Guideline Index for Children and Adolescents, an index that includes variety (19). However, it was also found that children in single parent families, with relatively higher income had a higher likelihood of eating patterns more consistent with recommendation for total dietary intake (i.e. nutrients and food) (47).

The present study has some strengths and limitations that deserve further discussion. This study is part of a population-based cohort study with a large sample size, conducted by an experience team, which contributes to minimize bias and support validity of the results. Another strength was the use of a specific index for toddlers that ensure variety within and among food groups, and also reflecting dietary adequacy (15). On the other hand, the index we used reflects dietary adequacy by comparison with recommendations of other country (US) and the index does not assess variety within fruit and vegetables due

to limited questions of the FFQ on these food groups, and just reflects whether or not children eat recommended number of servings of these two food groups. In this study, we also made an assumption that food variety is directly related to diet quality but we were unable to validate this assumption. Another limitation was the non-validation of the index, although methodology is based on sound principals, such as adherence to dietary guidelines. Furthermore, for some of the reported associations, the temporal sequence cannot necessarily be determined (for those variables assessed at the same age), and thus, we cannot discard a potential reverse causality bias.

In conclusion, this study shows that 4 years old children are consuming as wide variety healthy foods as is recommended. When studying its related factors, sedentary behaviours, such as a high number of media screening hours (2 or more hours per day) and a no regular practice of physical exercise were associated with a decreased dietary variety. Underweight children and those never breastfed or breastfed for less than 4 months had also less dietary variety.

Mother and family characteristics also showed to influence dietary variety of young children. Children from less educated and less physically active mothers presented less dietary variety. A traditional family structure with no siblings and living with both parents increased the probability of having less dietary variety at 4 years of age.

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Table 1 – Distribution of the Healthy Dietary Variety Index and its individual food groups in the Generation XXI sample (n=3962).

	Starchy Foods	Vegetables	Fruit	Meat, fish and alternatives	Dairy Foods	Healthy Variety Index
Mean	0.68	0.83	0.77	0.88	0.77	0.78
Standard Deviation	0.17	0.21	0.30	0.13	0.16	0.11
Minimum	0.02	0	0	0.03	0	0.25
Maximum	0.99	1	1	1	1	1

Possible range score: 0-1; 1 represents a higher variety and adequacy.

Table 2 – Descriptives of the child, mother and family characteristics and univariate associations with the Healthy Dietary Variety Index.

	n (%)	Healthy Variety Index Mean (SD)	Crude β-coefficient (95%CI)
CHILD'S CHARACTERISTICS AT BIRTH			
Child's sex			
Female	1921 (48.5)	0.78 (0.11)	0.001 (-0.006;0.008)
Male	2041 (51.5)	0.78 (0.11)	Ref.
Type of delivery			
Vaginal	2419 (61.1)	0.79 (0.11)	0.003 (-0.004;0.010)
Caesarean	1543 (38.9)	0.78 (0.11)	Ref.
Weight for gestational age*			
Small	551 (14.2)	0.77 (0.11)	-0.012 (-0.032;0.008)
Appropriate	3175 (82.0)	0.79 (0.11)	0.002 (-0.016;0.020)
Large	146 (3.8)	0.79 (0.12)	Ref.
CHILD'S CHARACTERISTICS AT 4 YEARS			
Media screening			
≤120 minutes/day	2826 (71.3)	0.79 (0.10)	Ref.
>120 minutes/day	1136 (28.7)	0.77 (0.11)	**-0.017 (-0.025;-0.010)**
Regular physical exercise*			
No	1237 (31.4)	0.77 (0.11)	**-0.028 (-0.036;-0.021)**
Yes	2708 (68.6)	0.79 (0.10)	Ref.
WHO z-score BMI*			
Underweight	18 (0.5)	0.70 (0.13)	**-0.085 (-0.134;-0.035)**
Normal weight	2659 (68.1)	0.79 (0.11)	Ref.
Overweight	823 (21.1)	0.79 (0.11)	0.005 (-0.003;0.013)
Obesity	406 (10.4)	0.77 (0.11)	-0.011 (-0.022;0.001)
Any breastfeeding duration			
<4 months or never	1365 (34.5)	0.78 (0.11)	**-0.014 (-0.022;-0.007)**
4-5 months	444 (11.2)	0.79 (0.10)	0.005 (-0.006;0.016)
≥6 months	2153 (54.3)	0.79 (0.11)	Ref.
MOTHER'S CHARACTERISTICS			
Age			
<25 years	622 (15.7)	0.78 (0.11)	**-0.014 (-0.025;-0.002)**
25-34 years	2617 (66.1)	0.79 (0.11)	-0.002 (-0.011;0.007)
≥ 35 years	723 (18.2)	0.79 (0.11)	Ref.
Education			
<9 years	1095 (27.6)	0.76 (0.11)	**-0.052 (-0.060;-0.043)**
9-12 years	1674 (42.3)	0.78 (0.11)	**-0.027 (-0.035;-0.019)**
>12 years	1193 (30.1)	0.80 (0.10)	Ref.
Smoking during pregnancy*			
Never	3123 (79.9)	0.79 (0.11)	Ref.
Ever	785 (20.1)	0.78 (0.10)	-0.008 (-0.016;0.001)
BMI before pregnancy*			
Underweight	149 (4.1)	0.80 (0.10)	0.005 (-0.013;0.022)
Normal weight	2410 (65.5)	0.79 (0.11)	Ref.
Overweight	804 (21.9)	0.78 (0.11)	-0.006 (-0.015;0.003)
Obesity	314 (8.5)	0.78 (0.11)	-0.009 (-0.022;0.004)

Table 2. **Continuation** – Descriptives of the child, mother and family characteristics and univariate associations with the Healthy Dietary Variety Index

	n (%)	Healthy Variety Index Mean (SD)	Crude β-coefficient (95%CI)
MOTHER'S CHARACTERISTICS			
BMI at 4 years*			
Underweight	43 (1.2)	0.82 (0.11)	0.027 (-0.006;0.059)
Normal weight	1740 (46.5)	0.79 (0.10)	Ref.
Overweight	1178 (31.5)	0.78 (0.11)	**-0.009 (-0.017;-0.002)**
Obesity	777 (20.8)	0.78 (0.11)	**-0.010 (-0.019;-0.001)**
Waist Circumference*			
<80.0 cm	1581 (42.4)	0.79 (0.10)	Ref.
80-87.9 cm	918 (24.6)	0.79 (0.11)	-0.003 (-0.012;0.006)
≥88.0 cm	1232 (33.0)	0.78 (0.11)	**-0.011 (-0.019;-0.003)**
Regular physical exercise*			
No	3139 (80.9)	0.78 (0.11)	**-0.018 (-0.027;-0.010)**
Yes	742 (19.1)	0.80 (0.11)	Ref.
FAMILY CHARACTERISTICS			
Number of siblings			
None	1845 (46.6)	0.78 (0.10)	**-0.013 (-0.024;-0.002)**
One	1671 (42.2)	0.79 (0.11)	-0.002 (-0.014;0.009)
Two or more	446 (11.3)	0.79 (0.11)	Ref.
Family structure*			
Both parents	3453 (87.2)	0.78 (0.11)	-0.007 (-0.017;0.004)
Single parent	475 (12.0)	0.79 (0.10)	Ref.
Other family structure	32 (0.8)	0.78 (0.10)	-0.023 (-0.062;0.016)

* These variables may not add to 3962 due to missing data.

95%CI: 95% confidence intervals; Ref.: reference category; WHO: World Health Organization; BMI: body mass index

Significant associations are in bold type.

Table 3 – Multivariate associations of the child, mother and family characteristics with the Healthy Dietary Variety Index.

	Model 1[a] Adjusted β coefficient (95%CI)	Model 2 [b] Adjusted β coefficient (95%CI)	Model 3 [c] Adjusted β coefficient (95%CI)
CHILD'S CHARACTERISTICS AT BIRTH			
Child's sex			
Female	0.001 (-0.006;0.008)	0.000 (-0.006;0.007)	0.000 (-0.006;0.007)
Male	Ref.	Ref.	Ref.
Type of delivery			
Vaginal	0.005 (-0.002;0.012)	0.004 (-0.003;0.010)	0.003(-0.004;0.010)
Caesarean	Ref.	Ref.	Ref.
Weight for gestational age			
Small	-0.014 (-0.033;0.005)	-0.011 (-0.031;0.008)	-0.016 (-0.035;0.004)
Appropriate	-0.002 (-0.020;0.016)	-0.001 (-0.018;0.017)	-0.005 (-0.023;0.012)
Large	Ref.	Ref.	Ref.
CHILD'S CHARACTERISTICS AT 4 YEARS			
Media screening			
≤120 minutes/day	Ref.	Ref.	Ref.
>120 minutes/day	**-0.012 (-0.019;-0.004)**	**-0.012 (-0.019;-0.004)**	**0.011 (-0.019;-0.004)**
Regular physical exercise			
No	**-0.022 (-0.029;-0.014)**	**-0.021 (-0.028;-0.014)**	**-0.020 (-0.027;-0.013)**
Yes	Ref.	Ref.	Ref.
WHO z-score BMI			
Underweight	**-0.081 (-0.130;-0.032)**	**-0.083 (-0.131;-0.034)**	**-0.083 (-0.131;-0.034**)
Normal weight	Ref.	Ref.	Ref.
Overweight	0.007 (-0.002;0.015)	0.007 (-0.001;0.015)	0.007 (-0.001;0.015)
Obesity	-0.005 (-0.016;0.006)	-0.004 (-0.015;0.007)	-0.004 (-0.015;0.007)
Any breastfeeding duration			
<4 months or never	**-0.012 (-0.019;-0.005)**	**-0.011 (-0.018;-0.004)**	**-0.010 (-0.018;-0.003)**
4-5 months	0.002 (-0.009;0.013)	0.003 (-0.008;0.013)	0.004 (-0.007;0.015)
≥6 months	Ref.	Ref.	Ref.
MOTHER'S CHARACTERISTICS			
Age			
≤25 years	-0,004 (-0,016;0,007)	0.004 (-0.008;0.016)	0.005 (-0.007;0.017)
25-34 years	-0,004 (-0,013;0,004)	0.000 (-0.009;0.009)	0.001 (-0.008;0.009)
≥35 years	Ref.	Ref.	Ref.
Education			
<9 years	**-0,052 (-0,061;-0,043)**	**-0.052 (-0.061;-0.043)**	**-0.051 (-0.060;-0.042)**
9-12 years	**-0,026 (-0,034;-0,018)**	**-0.025 (-0.033;-0.017)**	**-0.025 (-0.033;-0.016)**
>12 years	Ref.	Ref.	Ref.
Smoking during pregnancy			
Never	Ref.	Ref.	Ref.
Ever	-0.004 (-0.012;0.005)	-0.002 (-0.011;0.006)	-0.003 (-0.012;0.005)
BMI before pregnancy			
Underweight	0.003 (-0.015;0.020)	0.003 (-0.014;0.021)	0.004 (-0.013;0.022)
Normal weight	Ref.	Ref.	Ref.
Overweight	0.001 (-0.008;0.009)	4.055E-5 (-0.009;0.009)	0.001 (-0.008;0.009)
Obesity	0.001 (-0.012;0.013)	0.000 (-0.012;0.013)	0.001 (-0.012;0.014)

Table 3. Continuation – Multivariate associations of the child, mother and family characteristics with the Healthy Dietary Variety Index.

	Model 1[a] Adjusted β coefficient (95%CI)	Model 2 [b] Adjusted β coefficient (95%CI)	Model 3 [c] Adjusted β coefficient (95%CI)
MOTHER'S CHARACTERISTICS			
BMI at 4 years			
Underweight	0.026 (-0.066;0.058)	0.026 (-0.006;0.058)	0.026 (-0.006;0.058)
Normal weight	Ref.	Ref.	Ref.
Overweight	-0.004 (-0.012;0.004)	-0.005 (-0.012;0.003)	-0.003 (-0.011;0.004)
Obesity	-0.001 (-0.010;0.008)	-0.001 (-0.010;0.008)	0.001 (-0.009;0.010)
Waist Circumference			
<80.0 cm	Ref.	Ref.	Ref.
80-87.9 cm	0.000 (-0.009;0.008)	-0.001 (-0.010;0.007)	-0.001 (-0.009;0.008)
≥88.0 cm	-0.003 (-0.011;0.005)	-0.004 (-0.012;0.004)	-0.003 (-0.011;0.006)
Regular physical exercise			
No	**-0.010 (-0.018;-0.001)**	-0.008 (-0.017;0.001)	-0.007 (-0.016;0.002)
Yes	Ref.	Ref.	Ref.
FAMILY CHARACTERISTICS			
Number of siblings			
None	**-0.023 (-0.034;-0.011)**	**-0.022 (-0.034;-0.011)**	**-0.023 (-0.034;-0.011)**
One	-0.011(-0.022;0.001)	-0.011 (-0.022;0.001)	-0.011 (-0.022;0.001)
Two or more	Ref.	Ref.	Ref.
Family structure			
Both parents	**-0.010 (-0.021;-0.001)**	**-0.012 (-0.023;-0.002)**	**-0.013 (-0.023;-0.002)**
Single parent	Ref.	Ref.	Ref.
Other family structure	-0.016 (-0.054;0.022)	-0.013 (-0.051;0.025)	-0.005 (-0.044;0.033)

[a] β adjusted for child's sex and mother's age and education.

[b] β adjusted for variables from model 1 plus media screening, breastfeeding duration and number of siblings.

[c] β adjusted for variables from model 2 plus child z-score BMI at 4 years.

95%CI: 95% confidence intervals; Ref.: reference category; WHO: World Health Organization; BMI: body mass index

Significant associations are in bold type.

CONCLUSIONS

This study conducted in a population-based sample suggests that 4 years old children spending more than 120 minutes per day in media screening, do not practicing regular physical exercise, underweight and never breastfed or breastfed for less than 4 months had less dietary variety. Children from less educated mothers and less physically active mothers also presented less dietary variety. Family structure characteristics, such as do not having sibling and live with both parents increased the probability of having less dietary variety at 4 years of age.

FINAL CONSIDERATIONS

The associations reported in this study are relevant to understand some of the factors related with dietary variety in preschool-aged children and gives an additionally information compared with previous literature by using an index that assesses both variety and adequacy of dietary intake and demonstrates an association with different study characteristics. Some of these characteristics have been previously described, such as maternal education and breastfeeding duration, supporting previous research, but other characteristics were scant or not related in specific with dietary variety, such as lifestyles and family environment, giving a new approach for this topic.

The index used in this thesis is extremely interesting not only from the research point of view, but has also potential to be used in public health. It can be helpful as monitoring tool to evaluate how well children comply with dietary recommendations, monitor changes in dietary patterns over time, or evaluate the effectiveness of public health nutrition programs. This index provides a simple method to quantify dietary variety and it is simpler to populations understand these concept. Therefore, it is simple, fast, not expensive and can be used also in developing countries, giving better information than other scores generally used, because it has also information about dietary adequacy.

For future research, it is important to test the validity and reliability of this index in different population settings to have a clearer understanding of its utility alongside with its discriminatory and predictive abilities in diverse groups of children.

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