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Patterns of complementary feeding introduction and associated factors in a cohort of Brazilian infants

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Abstract

Background Understanding the timing of food introduction in infants is essential for promoting optimal complementary feeding practices. However, existing studies often rely on cross-sectional data, limiting the ability to capture age-specific patterns. We aimed to describe food introduction during the first year of life by identifying patterns related to age at food introduction and associated factors in a cohort of Brazilian infants.

Methods Data were collected through standardized questionnaires administered to mothers via face-to-face interviews during the infant's first month of life and at 3, 6, 9, and 12 months of age. Additionally, two telephone interviews were conducted at 2 and 4 months of age. Information regarding food intake was assessed using a list of 48 foods, with two key aspects recorded: whether the food was introduced (yes/no) and the age at introduction. To define food introduction patterns, we employed k-means cluster analysis. Hierarchical Poisson multiple regression was employed to examine the associations between sociodemographic, biological, and healthcare factors and patterns of food introduction.

Results Three distinct patterns were identified and named according to their main characteristics: Pattern 1 – "Low Infant Formula and Timely CF Introduction"; Pattern 2 – "High Infant Formula and Early CF Introduction"; and Pattern 3 – "High Infant Formula and Later Ultra-processed Food Introduction". Breastfeeding at six months showed a positive association with Pattern 1 (PR = 1.40; 95% CI = 1.10–1.80), while bottle use at four months was negatively associated with Pattern 1 (PR = 0.68; 95% CI = 0.53–0.87). No variables studied exhibited an association with Pattern 2. For Pattern 3, higher prevalences were observed among children whose mothers were aged < 20 years (PR = 1.54; 95% CI = 1.13–2.01) or > 34 years (PR = 1.42; 95% CI = 1.04–1.93). Not receiving guidance on the recommended duration of breastfeeding and complementary feeding during prenatal care was associated with a higher prevalence of children in this pattern (PR = 1.35; 95% CI = 1.01–1.80).

Conclusions We identified three distinct patterns of age at food introduction in the study population, although none perfectly aligned with Brazilian or WHO dietary recommendations. These findings underscore the need for targeted interventions to promote timely and healthy complementary feeding practices in Brazilian infants.

Keywords Child nutrition, Complementary feeding, Dietary patterns, Cluster analysis

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Background

The World Health Organization (WHO) recommends the introduction of solid foods at 6 months of age combined with continued breastfeeding until at least 2 years of age [1]. Current Brazilian guidelines for feeding children under two years of age, although predating the WHO's most recent publication in this area [2], are closely aligned: they include the timely introduction (after six months of age) of complementary foods (CFs), dietary diversity, specific food groups, and the avoidance of unhealthy foods and beverages such as ultra-processed foods [3].

Although the evidence is not conclusive [3], there are studies suggesting that the early introduction of CFs reduces the duration of breastfeeding and the absorption of important nutrients such as iron from breast milk and increases the risk of anaemia [4] and obesity [5]. However, late introduction (beyond six months) of CF also seems unfavourable, as exclusive breastfeeding does not fully meet the energy and nutritional needs of the infant from 6 months of age onwards, thereby increasing the risk of malnutrition, micronutrient deficiency [6], and future food allergies [7].

Since 2013, a national strategy for the promotion of breastfeeding and healthy complementary feeding has been implemented in Brazil [8]. The main objective of this program is to train and organize the work process of primary healthcare professionals to promote these recommendations using a problem-posing methodology. However, this program has encountered many obstacles to its wide implementation, and the most recent data indicate that the early introduction of complementary feeding and consumption of unhealthy foods in early life continues to be a very relevant public health problem [9, 10].

Data from the Brazilian Ministry of Health's National Study of Child Food and Nutrition (ENANI, in Portuguese), collected in 2019, showed that 86.3% of children aged 6 months had already been introduced to CFs and that 80.5% of children aged 6–23 months had already consumed ultra-processed food products [11]. However, breastfeeding rates in Brazil are increasing. The rate of exclusive breastfeeding was 45.8% among children under six months of age in 2019, which was higher than that reported in 1996 (26.9%), and complementary breastfeeding among children under one year of age increased from 36.6% in 1996 to 52.1% in 2019 [12].

Internationally, problems with the quality and timing of CF introduction have been reported in low-, medium-, and high-income countries. A study carried out in 2012 using data from Latin America and the Caribbean found that more than half of the children had already received CF before the age of 6 months in 14 out of the 19 countries studied [13]. The situation of complementary feeding at the global and regional levels is reported within the UNICEF global database. Nearly one-third of infants aged 4–5 months were already fed solid foods, whereas nearly 20% of 10–11-month-old infants did not consume solid foods during the day prior to their survey. Of particular concern is the low percentage (28.2%) of children aged 6–23 months receiving a minimally diverse diet. Among the five countries, 14–79% of the children aged 6–23 months consumed high-sugar foods the day before the interview [14].

An important aspect of the Brazilian literature regarding the timing and quality of introducing CFs is that most studies have analysed cross-sectional data to assess consumption patterns at different ages [10, 11, 15]. Prospective studies conducted in Brazil have not investigated the exact age of onset of each food item [16–19]. Hence, there is a lack of knowledge of the exact age at which different foods are introduced into an infant's diet, which hinders the development of effective interventions for the promotion of timely and healthy complementary feeding. In addition to the lack of knowledge of the exact age at which different foods were introduced into an infant's diet, the introduction of each food/food group was usually analysed separately without multivariate analysis, which decreases the strength of their findings. This study aims to fill these gaps in the literature. Specifically, we aimed to describe food introduction during the first year of life by identifying patterns related to age at food introduction using cluster analysis and associated factors in a cohort of Brazilian infants.

Methods

Study design and location

This study was a prospective cohort study. We examined data from the CLaB (Botucatu Infant Cohort) study, whose general objective was to describe events and situations related to the health of mothers and infants during the first year of life, including morbidity, growth, development, and food consumption and its determinants [20]. Botucatu is a city located in the south-central region of the state of São Paulo, Brazil, with 139,480 inhabitants. It had a human development index of 0.800, which was higher than that of the country (0.754). Furthermore, when observing the per capita GDP value, the municipality ranks second in its geographical region and 226th in the state (out of a total of 645 municipalities), placing the municipality in a favourable position [21]. According to data from the State System of Data Analysis (SEADE) Foundation, in 2015, the infant mortality rate was 12.6 per thousand live births, which is lower than that observed in Brazil in the same year (15.3 per thousand live births) [22].

Participants

The cohort included mothers and their babies born between June 29, 2015, and January 11, 2016. Participants were approached and invited to participate when attending a municipal government health care unit, which provided a neonatal screening service that offered centralized care to all newborns in the municipality's two maternity wards (one public, the other private). These are all maternity hospitals in the city, which provides cohort population representation for this study.

The inclusion criteria for the CLaB study were gestational age > 32 weeks, birth weight > 1500 g, age younger than 30 days, ability of the mother to answer face-to-face and telephone interviews, and residence in an urban area of the municipality. In the present study, twin babies and/or those with diseases or malformations that negatively impact breastfeeding, as well as those whose mothers had conditions that prevented breastfeeding, were excluded.

Sample size

In this study, participants were selected from the cohort formed at the baseline of the parent study (CLaB study), whose original sample size (n = 656) was reported elsewhere [22]. In the current study, 15 infants were excluded from the original sample of the CLaB study: 12 due to being part of a twin pregnancy, one because the mother had undergone mastectomy, one because the mother tested positive for human immunodeficiency virus (HIV), and one because the baby had a cleft lip and palate.

Figure 1 illustrates the flowchart depicting the cohort's follow-up until the infants reached 12 months of age. The sample comprised 569 infants and their mothers, reflecting an 8.9% attrition rate during the follow-up period. Subsequently, during cluster formation, an additional 2 children were excluded due to missing dietary data, resulting in a total of 567 infants.

Data collection

Data were collected through the administration of standardized paper questionnaires to mothers via face-to-face interviews conducted at the infant's first month of life and subsequently at 3, 6, 9, and 12 months of age, all of which were carried out at their residences. Additionally, two interviews were conducted via telephone when the infants were 2 and 4 months old.

In the first interview, socioeconomic factors included total family income, mother's education at the time of delivery (years), maternal age at delivery (years), maternal work status (yes, no), demographic self-reported maternal skin colour (white, black, brown, yellow or Asian), living with partner (yes, no), health data (parity, prenatal care service-public or private), receiving counselling on breastfeeding and CF introduction during prenatal care (yes, no), having completed seven or more prenatal appointments (yes, no), child birth weight (grams) and birth mode (vaginal, c-section). These variables were selected to characterize the sample and have the potential to be associated with patterns of introducing complementary feeding, as observed in Brazilian studies [20, 23, 24].

According to the IBGE (Demographic Censuses by the Brazilian Statistics Institute), self-reported skin colour is the best option for obtaining this information; therefore, to study this variable, the following options were presented (literal translation): black, brown, white, yellow, Asian, and yellow/red or indigenous [25]. In the CLaB study, we asked the mother to indicate what her skin colour was among these options. In the analyses, we tested the association between this variable and the outcomes, and as there were no differences between the black, brown, and yellow categories but rather between these and the white category, we chose to categorize the variable skin colour as white/nonwhite (white/nonwhite). We also noted that none of the mothers declared themselves to be red-skinned or indigenous.

Questionnaires on infant and maternal morbidity, health, and utilization of services were administered at 1, 3, 6, 9, and 12 months in the household. Food intake was assessed during these periods, as well as at 2 and 4 months, through telephone interviews. The data collected included information on pacifier use (yes, no) and bottle use (yes, no) at 4 months of age.

Food consumption was assessed with two questions: the introduction of each food (yes or no) and the age at first introduction (recorded in days). During all interviews, mothers were additionally queried about any foods that had not been previously reported, as introduced in prior interviews.

The questionnaire on food intake, developed by us, assessed the introduction of 48 food items to the infant's diet (yes, no), including various types of milk (formulas, fluid, or powdered cow's milk), yoghurts or other dairy products, water and other liquids (teas, natural and artificial juices, soft drinks), and solid foods (fruits, vegetables, cereals, pasta, soups, legumes, meat, and ultra-processed foods, such as powdered chocolate, biscuits, sweets, and treats). The list of food items was based on previous national [26, 27] and regional surveys [28] (Supplementary Table 1).

The consumption of breast milk was also investigated at all stages of the study, but it did not enter the formation of patterns, as we verified the relationship between exposure to breast milk and patterns of food introduction.

For the analyses, the 48 foods were categorized into 19 food groups based on nutritional similarity, usage type, and/or processing category: 1-Cow's milk; 2-Infant

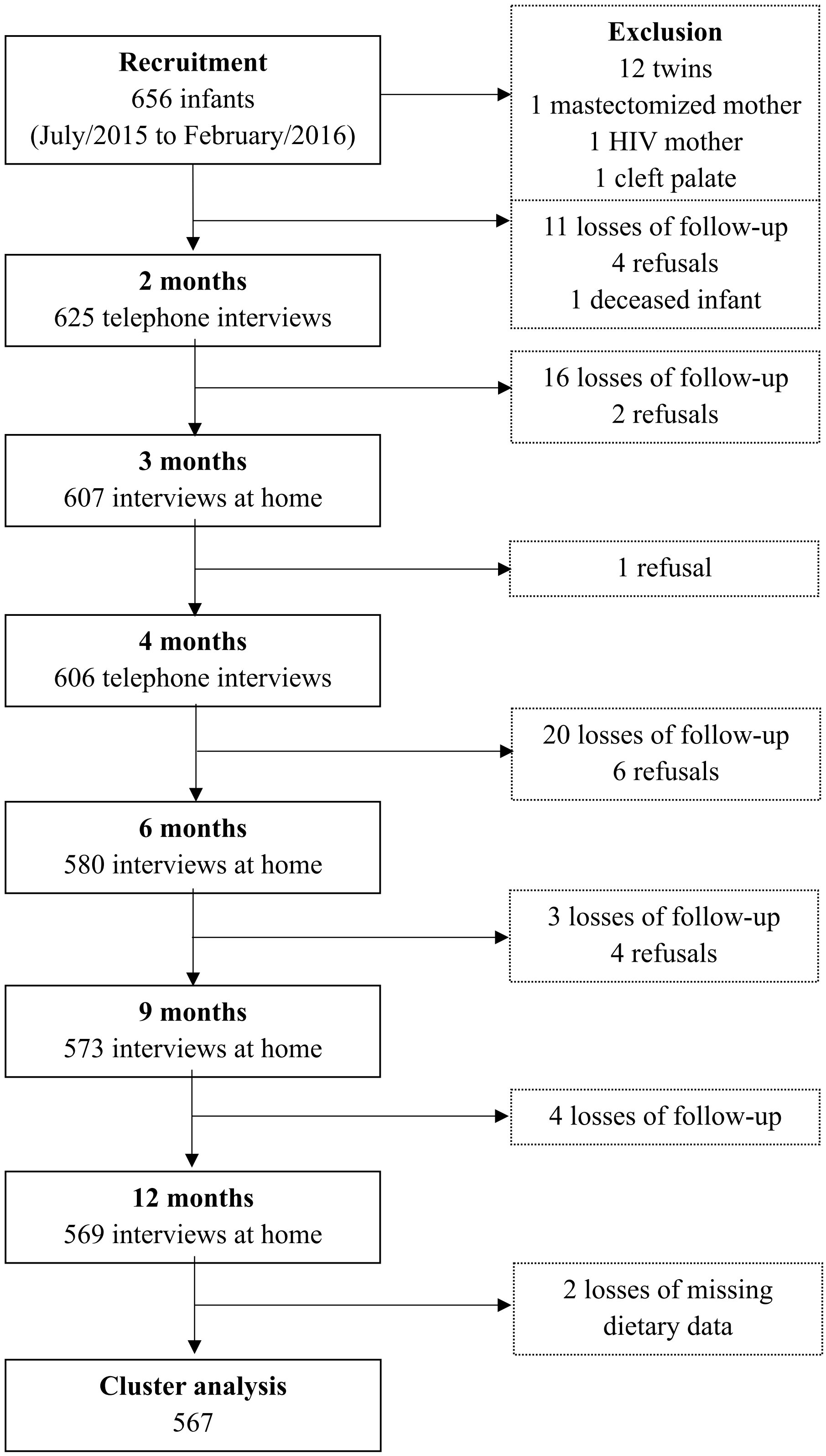

Fig. 1 Flowchart illustrating the formation of the cohort and subsequent follow-up. Location: Botucatu, Brazil, 2015–2016

formula; 3-Water and tea; 4-Powdered chocolate and flour to add to milk; 5-Sugar, honey, and sweetener; 6-Natural fruit juices; 7-Sugar-sweetened processed juices, soft drinks; 8-Cheese; 9-Yoghurts and petit-Suisse cheese; 10-Fruits; 11-Industrialized infant food, powdered soup, and ready-made seasonings; 12-Vegetables; 13-Rice, pasta, tubers; 14-Legumes; 15-Beef, pork, and chicken meat, offal, and eggs; 16-Fish; 17-Sausages (sausage, nuggets, bologna, salami, ham), pizza, and hamburger; 18-Simple biscuits and bread; 19-Stuffed biscuits, sweets, and other candies. In Supplementary Table 2, we describe the 48 foods, the group formation process, and the corresponding statistically significant values that contributed to their inclusion in the clusters.

The foods in our study were classified according to the NOVA criteria [29]. Therefore, we grouped yoghurt and petit-Suisse cheese, which are ultra-processed, separately from cheese, which is considered a processed food. Groups 4, 7, 9, 11, 17, and 19 consisted of ultra-processed foods; groups 1, 2, 3, 6, 8, 10, 12, 13, 14, 15, 16, and 18 were composed of foods classified as in *natura*, culinary ingredients/homemade, or processed foods.

Statistical analyses

Categorical data are described as absolute numbers and proportions. Continuous data with an approximately normal distribution are presented as the means and standard deviations or as medians and interquartile ranges, when otherwise.

Analyses were performed using the Statistical Package for the Social Sciences (SPSS® v. 20 for Windows®). To identify the patterns of food introduction in the first year of life, k-means cluster analysis was used. The cluster analysis classified the infants according to the average age at which each food/food group was introduced into the diet, thereby generating different groups. Some food/food groups whose data were not statistically significant (sugar-sweetened processed juices/soft drinks; honey, sugar, and sweeteners) were removed from the analysis. The youngest age of the child at which the first offering of any food within each group occurred was considered in the analyses for the formation of patterns.

Data clustering is a technique that consists of partitioning a set of data into groups according to a dissimilarity function. Clustering K (predefined groups) is a nonhierarchical exploratory multivariate technique that uses the measurement of Euclidean distance. The K-means clustering method classifies objects into multiple groups such that intracluster variation is minimized by the sum of the squares of the Euclidean distances between the items and their centroids [30].

We considered this approach to be the best solution to group individuals by the age of introduction of foods, thus generating patterns and highlighting the purpose of separating children and mothers with different behaviours and then investigating whether socioeconomic, demographic, and health factors were associated with the allocation of each pattern.

Poisson regression was employed to examine the determinants of each food introduction pattern (outcomes). Initially, bivariate analyses were conducted to assess the relationships between explanatory variables and outcomes. Explanatory variables that reached a significance level of $p < 0.25$ in the association test for the variable or at least one of its categories were considered for the next stage: multivariate analysis.

The explanatory variables were grouped into distal, intermediate, and proximal blocks. The distal block was composed of socioeconomic and demographic variables, such as self-reported maternal skin color (white or non-white), mother's education at the time of delivery (≤8, 9–11, and ≥12 full school years), mother's age at delivery (≤19, 20–34, and ≥35 years), maternal work status (unemployed, employed with paid leave, or employed without paid leave), family income per capita (quartiles), parity (primiparous or multiparous), and living with a partner (yes or no). The intermediate level was composed of variables related to health care, such as prenatal care service (public or private), having received counselling on breastfeeding and introducing CF during prenatal care (yes or no), and having attended seven or more prenatal appointments (yes or no). The proximal level included infants' characteristics, such as birth weight (≥2500; <2500 g), route of birth (vaginal or caesarean delivery), use of a pacifier at 4 months of age (yes, no), use of a bottle at 4 months of age (yes, no), and breastfeeding at 6 months of age (yes, no) (Supplementary Fig. 1).

For the multiple Poisson regression analyses, a hierarchical approach was employed. Variables with $p < 0.25$ were adjusted for factors allocated in the same and preceding blocks but not for those located at subsequent hierarchical levels [31]. Associations between exposure and outcomes were considered statistically significant at $p < 0.05$.

Ethical aspects

The parent study, the CLaB study, was approved by the Botucatu Medical School Ethics Review Committee (CAAE number: 37337314.3.0000.5411) on 11/01/2014. This subproject was approved on 03/08/2016 (CAAE number: 38403914.2.0000.5411).

The data collection process adhered to the principles outlined in the Helsinki Declaration. All recommended ethical procedures were followed, and prior to participating in the initial interview, all mothers willingly signed an informed consent form.

Results

Table 1 presents the characteristics of the studied sample. Most of the mothers reported having white skin (62.7%), while the others reported having brown (28.3%) or black (9.0%) skin (data not shown). At the time of delivery, most mothers (71.2%) were 20–34 years of age. Regarding schooling, 16.5% had up to eight full years, which, according to the Brazilian school curriculum, constitutes elementary education equivalent to the *middle school* level in the United States. Regarding maternal work status, 43.2% did not work, 51.2% of the mothers were employed and on maternity leave, and 5.6% were employed but not on maternity leave. Most of the mothers lived with a partner (87.7%) and used public services for prenatal care (66.1%) (Table 1).

Among the infants, 51.6% were born by caesarean section, and 5.9% were classified as having a low birth weight. At 4 months of age, most infants used pacifiers and bottles (Table 1). At two months of age, 80% of the babies were breastfed; at 4 months, 67.5%; at 6 months, 60.9%; and at 12 months, 35.5%. The rates of exclusive breastfeeding were 71.4% in the first month of life and 2.5% at 6 months (data not shown in tables).

Table 2 shows that, in ascending order, the median age at which complementary feeding (CF) was introduced varied, ranging from 60 to 330 days for infant formula and simple infant food/noodles/powdered soup/ready-made seasonings, respectively. Water/tea constituted the second-earliest group of foods to be introduced (median = 120 days). Sweet foods, such as powdered chocolate/flours and yoghurts, were introduced around 180 days, along with legumes and meat. The median age at which cow milk was introduced was 180 days (Table 2).

The analyses for cluster formation involved only 567 infants. Three patterns of food introduction were identified: Pattern 1 included 234 infants (41.3%), Pattern 2 included 157 infants (27.7%), and Pattern 3 included 176 infants (31.0%).

Table 3 describes the average ages of introduction for each food item and the proportion of infants who had the food item incorporated into their diet within the first year of life in each pattern.

Pattern 1 was characterized by the lowest proportion of infants who received milk formula and first received solid CF at approximately 5–6 months of age. The foods introduced earlier in this pattern were water/tea (121 days, 98.7%), fruit (154 days; 98.3%), and natural fruit juices (160 days; 94.4%). The food groups introduced later in Pattern 1 included simple biscuits and bread (302 days; 49.6%); infant formula was rare and had an average introduction at 295 days of age (1.3%); and stuffed biscuits, sweet, and other candies (70.9%) and fish (38.5%) were introduced at a mean 265 days of age

Table 1 Infants' and mothers' baseline characteristics Botucatu, Brazil, 2015–2016. (*N* = 569)

Characteristic	N[#] (%)
Mother's skin color	
White	357 (62.7)
Nonwhite (Black, Brown, Yellow or Asian)	212 (37.3)
Mother's age at delivery, years	
20–34	405 (71.2)
≤ 19	76 (13.4)
≥ 35	88 (15.4)
Schooling, full years of study	
≥ 12	113 (19.9)
9–11	362 (63.6)
≤ 8	94 (16.5)
Total family income per capita, quartile*	
1st quartile (136.52 US$)	143 (25.1)
2nd quartile (250.15 US$)	130 (22.8)
3rd quartile (383.40 US$)	152 (26.8)
4th quartile (500.00 US$)	144 (25.3)
Parity	
Primiparous	286 (50.3)
Multiparous	283 (49.7)
Maternal work status outside the home	
No	246 (43.3)
Yes, and on maternity leave	291 (51.1)
Yes, and not on maternity leave	32 (5.6)
Living with a partner	
Yes	499 (87.7)
No	70 (12.3)
Mother received prenatal orientation about BF** and CFI*	
Yes	193 (25.7)
No	376 (74.3)
Prenatal care service type	
Public	329 (66.1)
Private	169 (33.9)
Number of prenatal appointments attended	
< 7	76 (15.3)
≥ 7	421 (84.7)
Delivery mode	
Vaginal	276 (48.4)
Caesarean	294 (51.6)
Infant's birth weight, g	
< 2,500	33 (5.9)
≥ 2,500	530 (94.1)
Use of pacifier at 4 months	
Yes	310 (57.1)
No	233 (42.9)
Use of bottle at 4 months	
Yes	371 (68.1)
No	174 (31.9)
Breastfeeding at 6 months	
Yes	340 (60.9)
No	218 (39.1)

[#] Differences in the total number are attributable to missing information

[*] Quartiles of monthly per capita household income in US dollars

[**] *CFI* Complementary food introduction

[***] *BF* Breastfeeding

Table 2 Frequency, median and interquartile range of infants at the time of the introduction of specific complementary foods, CLaB Study, Botucatu, Brazil, 2015–2016. ($N=569$)

Food Group[3]	Introduction n (%)	Median (days)	Interquartile range
Infant formula[2]	337 (59.2)	60	20 – 120
Water and tea[1]	559 (98.1)	120	60 – 150
Natural fruit juices[1]	545 (95.6)	150	150 – 240
Fruits[1]	561 (98.4)	150	120—150
Rice, pasta, and tubers[1]	570 (100.0)	160	150 – 180
Vegetables[1]	568 (99.6)	165	150 – 180
Yoghurt, and petit Suisse cheese[2]	523 (91.8)	170	135 – 240
Legumes[1]	554 (97.4)	180	150 – 180
Cow's milk[1]	433 (76.0)	180	142. – 265
Beef, pork, chicken meat and offal, eggs[1]	563 (99.1)	150	150 – 210
Chocolate powders and flour to add to milk[2]	373 (65.4)	180	150 – 240
Fish[1]	194 (65.9)	270	240 – 300
Stuffed biscuits, sweets, and other candies[2]	387 (68.1)	280	240—330
Sausages (sausage, nuggets, sausage, bologna, salami, ham, pizza industrialized, hamburger)[2]	104 (18.3)	290	240 – 330
Cheese[2]	55 (9.6)	300	270 – 330
Simple biscuits and breads[2]	279 (49.0)	330	300 – 330
Industrialized infant food, noodles, powdered soup, and ready-made seasonings[2]	134 (23.6)	366	366 – 366

1-Unprocessed or minimally processed foods

2- Ultraprocessed foods

3—Sugar, honey and sweetener and sugar-sweetened processed juices and soft drinks food groups were not included in the clustering analysis

(Table 3). To summarize the characteristics of this pattern, it was named "Low Infant Formula and Timely CF Introduction."

Pattern 2, called "High Infant Formula and Early CF Introduction", was characterized by a high proportion of children who were fed both cow's milk (93%) and infant formula (100%), consumed powdered chocolate and flour to add to milk (90.4%), and stuffed biscuits, sweets, and other candies (87.3%). CF was generally introduced to infants before 4–5 months of age. Simple biscuits/bread, sausages, and butter and cheese were introduced later than infants in Pattern 1 (313, 285, and 279 days, respectively). In contrast, the foods offered earlier within this pattern were infant formula at 61 days of age (100%), water and tea at 75 days of age (98.7%), fruits (98.7%) and natural juices at 132 days of age (98.1%), and rice/pasta and vegetables at 146 (100%) and 147 days (100%), respectively (Table 3).

Pattern 3, called "High Infant Formula and Later Ultra-processed Food Introduction", was characterized by the lowest proportion of infants who had cow's milk (52.8%), stuffed biscuits/sweet (47.7%), powdered chocolate and flour to add to milk (36.7%), and simple biscuits and bread (38.6%) introduced in their diet during the first year of life. This pattern generally presented a greater average introduction age for the various CF groups. The foods offered the latest to infants in this pattern were simple biscuits and bread, followed by stuffed biscuits/sweets, at an average of 336 and 307 days, respectively. Cheese was introduced at an average of 300 days, and sausages were introduced at 293 days. Furthermore, in this pattern, infants were fed infant formula (89 days, 100%) and other liquids, such as water and tea, earlier (111 days, 97.2%) than those in Patterns 1 or 2 (Table 3).

Pattern 2, encompassing 27.7% of the cohort, deviated the most from recommended practices, primarily due to a notable proportion of children receiving early introductions to cow's milk, formula, and sweets. This pattern classified children who initiated complementary feeding at an earlier age with a variety of foods and food groups. Pattern 3 comprised the highest percentage of children who received infant formula introduced at an earlier age compared to the other two patterns. Additionally, this pattern included children for whom the introduction of a substantial portion of ultra-processed foods occurred later and less frequently. Pattern 1 consisted of children who were introduced to vegetables, yoghurt, cow's milk, chocolate milk, biscuits/breads, and processed meats earlier than those in Pattern 3 and later than those in Pattern 2 (Table 3).

The patterns did not differ in terms of the proportion of infants who received water/tea, rice/pasta, fruits,

Table 3 Complementary food introduction patterns during the infants' first year of life CLaB study, Botucatu, Brazil, 2015–2016. ($N=567$)

Food	Pattern 1 $n=234$ (41.3%)		Pattern 2 $n=157$ (27.7%)		Pattern 3 $n=176$ (31.0%)	
	Yes n (%)	Mean age* (days)	Yes n (%)	Mean age* (days)	Yes n (%)	Mean age* (days)
Infant formula	3 (1.3)	295	157 (100)	61	176 (100)	89
Water and tea	231 (98.7)	121	155 (98.7)	75	171 (97.2)	111
Natural fruit juices	221 (94.4)	160	154 (98.1)	132	168 (95.5)	153
Fruits	230 (98.3)	154	155 (98.7)	132	175 (99.4)	146
Rice, pasta, and tubers	234 (100)	166	157 (100)	146	176 (100)	169
Vegetables	232 (99.1)	168	157 (100)	147	176 (100)	167
Yoghurt and petit Suisse cheese	219 (93.6)	182	153 (97.5)	161	149 (84.7)	209
Legumes	228 (97.4)	182	154 (98.1)	162	171 (97.2)	204
Cow's milk	191 (81.6)	184	146 (93.0)	168	93 (52.8)	258
Beef, pork, and chicken meat and offal	230 (98.3)	187	157 (100)	166	176 (100)	187
Chocolate powders and flour	164 (70.1)	196	142 (90.4)	155	65 (36.9)	241
Fish	90 (38.5)	265	67 (42.7)	260	36 (20.5)	271
Stuffed biscuits, sweets, and other candies	166 (70.9)	265	137 (87.3)	247	84 (47.7)	307
Sausages	58 (24.8)	255	35 (22.3)	285	10 (5.7)	293
Cheese	23 (8.9)	302	30 (19.1)	279	1 (0.6)	300
Simple biscuits and breads	116 (49.6)	302	94 (59.9)	313	68 (38.6)	336
Industrialized infant food, noodles, powdered soup, and ready-made seasonings	55 (23.5)	204	46 (29,3)	182	31 (17.6)	195

* Mean age = k-means

vegetables, fruit juices, *petit Suisse* cheese/yoghurt, or meat during the first year of life. However, introduction occurred at an earlier age for infants in Pattern 2, with no significant differences between Patterns 1 and 3 (Table 3).

There were differences in the proportion of infants who had some foods included in their diet. In the case of milk formula, this food reached only 1.3% of infants in Pattern 1, whereas it reached 100% of infants in Patterns 2 and 3. Chocolate powders were introduced into the diets of 70.1% of the infants in Pattern 1, 90% in Pattern 2, and only 36.9% in Pattern 3.

The results of the separately conducted modelling, with outcomes related to each of the clusters, are summarized in Table 4. This table presents only the bivariate analyses and those adjusted for factors selected in the preceding blocks and in the block where the factor is located, according to the criteria outlined in methods for hierarchical analysis. In the case of Pattern 1, only proximal variables were associated: breastfeeding at 6 months of age was linked to an increased likelihood (by 40%) of belonging to Pattern 1; the use of a bottle at 4 months was associated with a 32% decrease in this probability. For Pattern 2, adolescent mothers demonstrated a 40% lower likelihood of having this pattern. However, this result did not reach the predetermined level of statistical significance ($p=0.055$), and no other factors were associated with membership in Pattern 2. The two extreme maternal age groups (< 20 and > 34 years) were associated with a greater prevalence of children in Pattern 3 than mothers aged 20 to 34 years. In the intermediate block, not receiving guidance on the recommended duration of breastfeeding and the appropriate age to start complementary feeding during prenatal care were associated with a greater percentage of children allocated to Pattern 3. In the proximal block, no factors associated with Pattern 3 were identified (Table 4).

Discussion

Three patterns of infant feeding introduction were identified based on the age at which various foods were first offered during the first year of life. The delayed introduction of solid foods, except for infant formula, was characterized by pattern 3, followed by patterns 1 and 2. Breastfeeding at six months was positively associated with pattern 1, which also exhibited a negative association with bottle use at four months. In pattern 3, higher prevalences were observed among children of mothers aged less than 20 years and over 34 years, as well as among those whose mothers did not receive guidance on breastfeeding and complementary feeding during the

Table 4 Factors associated with complementary food introduction patterns (clusters) during infants' first year of life, CLaB study, Botucatu, Brazil, 2015–2016. (*N* = 567)

Variable	Pattern 1			Pattern 2			Pattern 3		
	Bivariate analysis **PR (95% CI)**	***Adjusted analysis PR (95% CI)***	***p***	***Bivariate analysis PR (95% CI)***	***Adjusted analysis PR (95% CI)***	***p***	***Bivariate analysis PR (95% CI)***	***Adjusted analysis PR (95% CI)***	***p***
Distal Level									
Mother's skin colour									
White*									
Nonwhite	1.06 (0.86–1.29)	-		0.94 (0.71–1.25)	-		0.99 (0.77–1.27)	-	
Mother's age at delivery, years		-							
20–34*									
≤ 19	0.85 (0.52–1.15)	-		0.61 (0.37–1.01)	0.63 (0.36–1.04)[h]	0.055	1,54 (1,13–2,10)	1.54 (1.13–2.01)[m]	0.006
≥ 35	0.93 (0.69–1.25)	-		0.83 (0.55–1.23)	0.88 (0.59–1.32)[h]	0.541	1,42 (1,04–1,93)	1.42 (1.04–1.93)[m]	0.027
Maternal education, years									
≥ 12*									
9–11	1.02 (0.78–1.33)	0.99 (0.74–1.32)[a]	0.445	0.92 (0.664–1.23)	0.93 (0.66–1.32)[i]	0.669	1.06 (0.77–1.46)	-	
≤ 8	1.28 (0.95–1.75)	1.15 (0.80–1.65)[a]	0.950	0.69 (0.43–1.11)	0.78 (0.46–1.33)-i	0.361	0.96 (0.62–1.46)	-	
Total family income per capita, quartile									
4th*									
1st	0.83 (0.61–1.14)	0.82 (0.59–1.15)[b]	0.252	1.32 (0.81–1.59)	1.12 (0.84–1.72)[j]	0.326	1.08 (0.77–1.55)	-	
2nd	1.23 (0.93–1.56)	1.15 (0.84–1.56)[b]	0.399	0.82 (0.56–1.22)	0.95 (0.62–1.47)[j]	0.821	0.89 (0.61–1.28)	-	
3rd	1.19 (0.91–1.56)	1.11 (0.81–1.51)[b]	0.516	0.75 (0.51–1.11)	0.93 (0.59–1.45)[j]	0.739	1.0 (0.71–1.40)	-	
Parity									
Multiparous*									
Primiparous	0.82 (0.67–1.00)	0.91 (0.74–1.14)[c]	0.419	1.20 (0.92–1.57)	1.15 (0.84–1.58)[k]	0.374	1.11 (0.87–1.42)	-	
Maternal work status									
Employed and on maternity leave*									
Employed but not on maternity leave	1.19 (0.81–1.76)	-		0.82 (0.42–1.61)	-		0.76 (0.52–1.63)	-	
Unemployed	1.01 (0.82–1.24)	-		1.03 (0.79–1.35)	-		0.76 (0.75–1.24)	-	
Living with a partner									
Yes*									
No	1.06 (0.80–1.42)	-		0.82 (0.52–1.29)	-		1.09 (0.76–1.55)	-	
Intemediate Level									
Mother received prenatal counselling about BF and CFI									
Yes*									
No	0.95 (0.77–1.17)	-		0.87 (0.67–1.15)	-		1.22 (0.93–1.60)	1.35 (1.01–1.80)[n]	0.043
Number of prenatal appointments attended									
≥ 7*									
< 7	1.20 (0.92–1.56)	1.20 (0.99–1.56)[d]	0.174	1.00 (0.67–1.48)	-		0.77 (0.51–1.16)	0.76 (0.51–1.15)[o]	0.195
Prenatal care setting									
Public service*									
Private service	0.80 (0.63–1.02)	0.81 (0.64–1.03)[e]	0.083	0.99 (0.67–1.48)	-		1.18 (0.90–1.53	-	
Infant's birth weight, g									
≥ 2.500*									
< 2.500	1.18 (0.82–1.70)	-		0.87 (0.47–1.61)			0.88 (0.50–1.57)	-	

Table 4 (continued)

Variable	Pattern 1			Pattern 2			Pattern 3		
	***Bivariate analysis* PR (95% CI)**	***Adjusted analysis PR (95% CI)***	***p***	***Bivariate analysis PR (95% CI)***	***Adjusted analysis PR (95% CI)***	***p***	***Bivariate analysis PR (95% CI)***	***Adjusted analysis PR (95% CI)***	***p***
Delivery mode									
Vaginal*									
Caesarean section	1.03 (0.84–1.24)	-		0.93 (0.72–1.21)	-		1.04 (0.82–1.34)	-	
Proximal level									
Breastfeeding at 6 months									
Yes*									
No	1.18 (0.97–1.44)	1.40 (1.10–1.80)[f]	0,007	1.01 (0.76–1.32)	-		0.794(0.61–1.04)	-	
Bottle use at 4 months									
No*									
Yes	0.85 (0.69–1.04)	0.68 (0.53–0.87)[g]	0.002	1.29 (0.94–1.76)	1.27 (0.93–1.74)[l]	0.132	1.01 (0.78–1.32)		
Pacifier use at 4 months									
No*									
Yes	1.08 (0.88–1.04)	-		1.08 (0.82–1.76)	-		0.85 (0.66–1.08)	-	

[*] Reference category

[a] adjusted for family income per capita and parity

[b] adjusted for maternal education and parity

[c] adjusted for family income per capita and maternal education

[d] adjusted for prenatal care setting

[e] adjusted for number of prenatal appointments attended

[f] adjusted for prenatal care setting, number of prenatal appointments attended and bottle use at 4 months

[g] adjusted for prenatal care setting, number of prenatal appointments attended and breastfeeding at 6 months

[h] adjusted for maternal education, family income per capita and parity

[i] adjusted for mother's age at delivery, family income per capita and parity

[j] adjusted for parity, mother's age at delivery and maternal education

[k] adjusted for family income per capita, mother's age at delivery and maternal education

[l] adjusted for mother's age at delivery

[m] no adjustment

[n] adjusted for number of prenatal appointments attended and mother's age at delivery

[o] adjusted for mother receiving prenatal counselling about CFI and mother's age at delivery

postnatal period. Socioeconomic variables did not influence membership in these patterns, indicating that interventions aimed at promoting healthy feeding practices early in life should target all socioeconomic strata within the community.

Infant formula and water/tea constituted the earliest groups of foods to be introduced, followed by natural fruit juice, with median introduction ages of 60, 120, and 150 days, respectively. Overall, ultra-processed foods were introduced later, with the group of powdered chocolate and flour added to milk being the first to be introduced into children's diets, with a median of 187 days. However, this practice is not recommended because it does not support healthy growth and development [1].

When considering all infants, regardless of the pattern in which the child was allocated, infant formula was the food with the lowest median age at introduction. This is not surprising because in Brazil, as well as in many other countries, the milk formula industry adopts aggressive and sophisticated marketing strategies, making them a safe alternative in cases where it is difficult to initiate or maintain exclusive breastfeeding [32]. Early weaning is usually the consequence of early use of milk formula. It is also worth noting that cow's milk was introduced into the diet of 60% of infants. The early introduction of this food is associated with potential harm to infant health. Cow milk contains a large amount of protein and is low in iron, which can promote dehydration and anaemia [33–35]. Early use of fluid cow milk by Brazilian infants is common, given that formulas are expensive for a large part of the population.

Regarding the quality of solid foods introduced into the infants' diets, it is noteworthy that most children in the three patterns received the types of foods recommended by the Brazilian food guide for children under two years of age [2], such as fruits, vegetables, meat, and legumes. However, these foods were introduced before six months of age, contravening the guideline that such foods should only be offered after the child reaches six months of age.

A positive aspect of infant feeding in our study was the lower average age at the introduction of unprocessed or minimally processed foods *versus* ultra-processed foods. However, many infants are exposed to sugary foods before 1 year of age, contrary to the current recommendations in Brazil (2) and worldwide [36] to avoid sweetened beverages and foods until two years of age.

Interestingly, we observed the introduction of ultra-processed foods, including yoghurts/petit-Suisse cheese, stuffed biscuits, sweets and candies, and chocolate powders, across all three patterns. This observation confirms that the consumption of these products during the first year of life poses a serious public health issue in Brazil [9, 37, 38]. The prevalence of such consumption is also a global concern [39]. The introduction of ultra-processed foods rich in sugars, sodium, fats, and chemicals, such as dyes and preservatives, can damage infant health in the short and long term. Studies have associated the consumption of these products during childhood with obesity, diabetes, and metabolic syndrome in addition to increased risks to cardiovascular health [40, 41].

For the quality of the infant's diet, it is important to understand the family's eating habits, which were not examined in our study. The availability of ultra-processed foods in this age group may reflect the foods offered by the family. In Brazil, the consumption of these foods has increased considerably in recent decades [42].

We found great variation between the three patterns relating to the average age at the introduction of some foods, such as cow's milk and milk formula, as well as the proportion of infants who were introduced to these foods. Regarding the other foods, the differences between the patterns were more subtle. None of the patterns conformed to a model or healthy standard according to Brazilian [2] and international [1] recommendations. However, Pattern 2 (27.7%) can undoubtedly be considered the most inadequate, as unhealthy foods were introduced more frequently and at earlier ages. Fortunately, this was least prevalent in the infant cohort population.

Only proximal factors influenced Pattern 1: bottle use (reducing prevalence) and breastfeeding (increasing prevalence). This result is explained by the inverse relationship between them: early introduction of CF and a shorter duration of breastfeeding are unequivocal and have already been confirmed in the literature [43]. Therefore, actions to promote healthy eating during early life should focus on two components: encouraging prolonged breastfeeding and timely introduction of appropriate CF. In Brazil, the focus of the National Strategy for Promotion of Breastfeeding and Healthy Complementary Feeding in the Brazilian Health System is on both components. However, there are many challenges in applying this strategy to all Brazilian primary health units and training health professionals [44].

Although this study focuses on the results from a single medium-sized city in the interior of a state, this city is part of the group of municipalities with populations between 100,000 and 500,000 inhabitants, which collectively account for approximately 28% of the Brazilian population. In this context, the results of this study may have relevant implications for Brazilian breastfeeding and complementary feeding strategies [8]. The frequent introduction of milk formula and cow's milk to infants, as well as other unhealthy foods, in the absence of clear sociodemographic characteristics associated with different patterns of food introduction highlights the need for more comprehensive and improved general education from healthcare professionals and parents regarding current recommendations for exclusive breastfeeding and breastfeeding duration, as well as healthy complementary feeding.

One advantage we had in Brazil was the publication and implementation of Resolution 06 (05/08/2020) within the scope of the National School Feeding Program (PNAE) to align the recommendations of the Food Guide for Younger Children 2 years with the PNAE recommendations. One of the recommendations to be highlighted is the absence of foods with sugar and other ultra-processed foods for children under two years of age and the availability of only in natura foods in public schools [45, 46]. However, extending these recommendations to private schools is still a challenge.

With the caveat of not reaching significance at the adopted critical p value ($p < 0.05$), being a teenage mother was protective against the infant in Pattern 2. This result is seemingly contradictory to those reported by recent studies [47, 48], which identified a greater consumption of ultra-processed foods in the infants of adolescent mothers. To explain this result, we hypothesized that such mothers have more access to current recommendations on infant feeding, possibly by accessing the web or during prenatal care. Adolescent pregnancy in primary healthcare is considered a priority of care [49], with an active search for prenatal consultations. Thus, one of the possible explanations is the greater proximity and care for health professionals. Qualitative studies in this locality could investigate the relevance of this hypothesis.

The fact that older mothers also have a greater likelihood of adhering to pattern 3 also deserves qualitative investigation. Our hypothesis is that older women are more likely to plan their pregnancies and seek information about healthy nutrition. Consequently, they are less likely to offer ultra-processed products to their children during the first year of life. On the other hand, it makes sense that not receiving guidance on breastfeeding and complementary feeding during prenatal care would increase the chances of belonging to pattern 3, as in this pattern, because all babies in this pattern received formula.

Among the limitations of our study, we emphasize challenges associated with the analytical method employed, specifically cluster analysis, in which the Euclidean distance serves as the metric to form clusters. The method is iteratively applied for various values of k, selecting outcomes that yield the most meaningful interpretation of the groups [30].

This approach to cluster formation is exploratory in nature and lacks measures of goodness of fit characteristic of inferential models. Although there are several complex statistical tests for evaluating the internal validity of cluster analysis results using the K-means method, these tests were not conducted. Despite this limitation, we maintain confidence in the valuable insights provided by our analysis regarding the clustering of infants based on the average age of food introduction.

The patterns identified through cluster analysis are, to some extent, influenced by the specific set of foods and their consumption frequencies within the studied population. This limitation restricts the comparability of our results with those of studies based on different sets of foods. Additionally, the list of surveyed foods, although extensive and based on dietary consumption surveys in the locality and the country, may have excluded certain foods capable of influencing pattern formation. Finally, we cannot rule out the possibility that social desirability bias may have influenced the responses of some mothers to our questions to some extent. This limitation is that neither our study nor previous ones about this issue were able to be avoided due to practical issues. Nevertheless, the fact that none of the interviewers were connected to the healthcare services used by the infants or their mothers may have reduced that source of bias.

The absence of psychosocial and cultural variables that could influence adherence to different complementary feeding (CF) introduction patterns is also a limitation. In future studies, we recommend expanding the range of variables to be investigated, considering other factors that may influence the age of introduction and the choice of each new food incorporated into the infant's diet throughout the first year of life. As this study focuses on a single medium-sized municipality, further research in different locations or with nationally representative data could advance the understanding of issues related to dietary introduction in Brazilian children.

Despite the limitations described in the previous paragraphs, our study has several strengths. The low rate of refusal, attrition, and missing information, coupled with its longitudinal design, supports the validity of our results. Moreover, there were no differences in socioeconomic or demographic characteristics between the participants who were followed and those who dropped out.

Conclusions

We identified three distinct patterns of age at food introduction in the study population, although none perfectly aligned with Brazilian or WHO dietary recommendations. Being breastfed at six months, as opposed to bottle-feeding at 4 months, were factors associated with pattern 1 – "Low Infant Formula and Timely CF Introduction". Having an adolescent mother or a mother over 34 years old increased the prevalence of babies in pattern 3 – "High Infant Formula and Later Ultra-processed Food Introduction", as well as being born to mothers who did not receive guidance on breastfeeding and introduction of complementary foods during prenatal care. No variable studied was associated with pattern 2 – "High Infant Formula and Early CF Introduction". These results emphasize the necessity for actions promoting healthy eating during early life to consistently focus on three components: encouraging prolonged breastfeeding, avoiding the use of other milks and bottles, and timely and appropriate selection of foods to be introduced into the infant's diet.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-024-05052-y.

Additional file 1: Supplementary figure 1. Theoretical hierarchical model for the introduction of complementary feeding in the first year of life Reporting guideline for organizational case studies.

Additional file 2: Food table.

Additional file 3: Supplementary table 2. Foods and food groups for cluster analysis. CLaB study, Botucatu, Brazil, 2015-2016.

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Authors' contributions

MAMA collaborated in the formulation of the research question, study design, data collection, and construction and cleaning of the database. Additionally, we performed the statistical analyses and wrote the first version of the manuscript. JEC and collaborated on the statistical analysis, interpretation of the results, and writing of the manuscript. EIOV collaborated with the statistical analysis and writing of the manuscript. AEMR and CBG contributed to the interpretation of the results, writing of the manuscript and review of the final version. MABLC formulated the research question, designed the study, contributed to the interpretation of the results, and wrote the manuscript. All authors reviewed and approved the final version of the current manuscript.

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

Declarations

Ethics approval and consent to participate
The matrix project, the CLaB study, was approved by the Botucatu Medical School of São Paulo State University Ethics Committee (CAAE number: 37337314.3.0000.5411) on 11/01/2014. This subproject was approved on 03/08/2016 (CAAE number: 38403914.2.0000.5411). All recommended ethical procedures were followed, and all mothers agreed to sign an informed consent form before participating in the first interview.

Consent for publication
Not applicable.

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

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