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ORIGINAL ARTICLE

Nutrition

Complementary feeding in infants born preterm: Aspects needing improvement

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Abstract

Objective: The aim of our study was to collect data on complementary feeding (CF) in preterm infants (PIs).

Methods: We enrolled PI ≤ 34 weeks of gestational age discharged from the neonatal intensive care unit (NICU) of the University Hospital of Padova. At 12 months of corrected age (CA), CF was investigated with questionnaires to the parents and a 24-h dietary recall. In a subgroup of newborns, we also evaluated bone status at a CA of 12 months using quantitative ultrasound.

Results: We studied 167 ex PI at 1 year of CA. CF was introduced in 67.1% of them between 5 and 8 months of chronological age, with fruit as the first food (81%, $n = 136$). Sweet drinks were consumed by 17.4% of our sample, and salt was added in 33.5% of cases. PIs, at 1 year CA, introduced extra energy compared to the theoretical requirement (121 ± 31 kcal/kg/day) and higher protein intake than recommended (39 ± 11 g/day), while the intake of both total lipids and carbohydrates was slightly lower. Vitamins and minerals were adequate, except vitamin D. Regarding bone status, we found a correlation between vitamin D intakes from the diet and bone parameters (metacarpus-bone transmission time: $r = 0.36$, $p = 0.01$) at 1 year of CA.

Conclusions: Our population of PIs started CF in agreement with current suggestions though with a notable heterogeneity and with some mistakes. Vitamin D intake was correlated with bone status at 1 year of CA.

KEYWORDS

bone status, feeding after discharge, preterm infants

1 | INTRODUCTION

The first 1000 days of life, from conception to the second year of life, is a fundamental time, especially for preterm infants (PIs), as nutrition in this period can significantly affect their future health.[1–4] However, PIs often experience extrauterine growth restriction,[5,6] a problem that can also continue after discharge from the neonatal intensive care unit (NICU). For this reason, complementary feeding (CF) in PIs can have a significant impact on long-term growth.[7] Indeed, there are few suggestions regarding CF in PIs.[3,8]

Several criteria were applied to start CF in PIs: body weight ≥5 kg[9,10] or 5–8 or 4–6 months of chronological or corrected age (CA)[10–12]; while in a recent position paper,[8] the onset of CF is suggested in PIs between 5 and 8 months of age, with the limit of 3 months of CA; the same guidelines available for term newborns must be applied for the type, sequence, or speed of food to choose. Some authors suggest that CF should start by including carbohydrates, proteins, and vegetable fats,[13] with an adequate supply of micronutrients.[14]

An Italian study highlighted the heterogeneous indications provided to parents by pediatricians when starting CF in PIs.[15] Furthermore, the start of CF in PIs is extremely variable in timing[16] and it is difficult to understand when other types of food are needed to meet preterm growth needs.[17]

Therefore, the main objective of our study was to collect comprehensive data on complementary foods in our PIs. The secondary objective was to collect data on bone status in PIs at 1 year of CA in a subgroup whose bone status had been previously analyzed during hospitalization.

What is Known

- Early feeding is known to significantly influence the future health of preterm infants (PIs).
- There are few suggestions regarding Complementary feeding (CF) after discharge in *PIs* and great heterogeneity in the time of weaning, type, sequence, and rate of introduction of foods.

What is New

- CF is started with a notable heterogeneity and low-caloric food.
- Protein intake is excessive and some aspects (sugar introduction, sweet drinks, salt) are to be avoided.
- Vitamin D intake correlates with bone status at 1 year of corrected age.

2 | METHODS

We enrolled PIs born at a gestational age (GA) ≤ 34 weeks discharged from the NICU of the Department of Women's and Children's Health of the University Hospital of Padova from January 2019 to November 2020. Infants with malformations, congenital infections, and metabolic disorders were excluded. The study was approved by the Hospital Ethics Committee (reference number 4374/AO/17) and informed consent was obtained from parents.

At the CA of 12 months, questionnaires that analyzed data related to the nutrition and eating habits of the postdischarge infants (breastfeeding or other type of formula administered during CF, duration of breastfeeding, any iron and vitamin D supplementation) and times and methods for starting complementary foods (starting age, first food introduced, meal replaced, time for introduction of various foods) were administered to the parents (see Files S1, S2, S3, and S4 for questionnaires on CF).

To build the questionnaires, we took into account the documents prepared by WHO,[18] FAO,[19] and the ESPGHAN 2017 guidelines on CF.[11]

Finally, the food intake assessment was collected using a 24-h dietary recall[20] reporting the intakes the day before the assessment, asking parents to specify the various foods for each meal of the day. An estimate of CF energy and nutritional intake was obtained and these data were processed and calculated with Metadieta® software version 3.4.1.1 by comparing them with the national recommended intakes of energy and nutrients.[21]

We recorded perinatal (GA, sex) and anthropometric data (weight, length, head circumference at birth, discharge, at 6 months, and at 1 year of CA); Fenton 2003 growth charts were used to define the anthropometric parameters and relative percentiles.[22]

A balance with a sensitivity of 1 g (Incubator 8000 SCVR, Drager-or-Tassinari Balance) was used to weigh PIs, while a meter with a sensitivity of 0.1 cm was used to measure total length and head circumference.

In a subgroup of newborns ($n = 50$) who had bone status analyzed during the neonatal age, we also evaluated bone status at 12 months of CA.

To analyze bone status (bone density, elasticity, and structure), we used quantitative ultrasound (QUS) on the second metacarpal bone of the left hand with DBM Sonic® BONE PROFILER (IGEA) as previously described.[23,24] The QUS methodology is safe for babies, is noninvasive and radiation-free, easy to use, and does not require sedation.[25,26] Briefly, the distance between electrodes and the speed of the ultrasound pulse are measured, with a precision <1%. These data allow the calculation of BTT (bone transmission time, μs), mirroring the bone condition because it reflects the density, elasticity, and bone structure. The results were compared with the body length growth curve, made by Ritschl in his work.[25] Metabolic bone disease (MBD) was defined when Z-BTT length (bone transmission time Z score) is <2 standard deviation (SD).[26,27]

All data on PIs were stored in a Microsoft Office Excel® 2013 file (Microsoft Society). SPSS® software version 15.0 (Statistical Packages for Social Science) was used for statistical analyses. Continuous variables were expressed as mean ± SD. Categorical variables are instead presented as a percentage frequency. The two-tailed Student's *T*-test for independent variables was used for comparison of variables, while contingency tables with χ^2 test were used to determine qualitative variables. Bone QUS data were analyzed

TABLE 1 Anthropometric parameters below the 10th percentile from birth to the first year of life **(*n* = 167)**.

	Birth	Hospital discharge	6 months of CA	12 months of CA
W (N–%)	32–19.2%	102–61.1%	53–31.7%	53–31.7%
L (N–%)	51–30.5%	93–55.7%	30–18%	24–14.4%
HC (N–%)	27–16.2%	83–49.7%	38–22.8%	30–18%

Abbreviations: CA, corrected age; HC, head circumference; L, length; N, number; W, weight.

cross-sectionally and longitudinally, using univariate models. The univariate linear model was used to investigate the association between continuous variables by determining Pearson's correlation coefficient. Statistical significance level at $p < 0.05$ was considered throughout the analyses.

3 | RESULTS

We studied 167 ex PIs at 1 year of CA (mean 11.9 months; SD ± 0.5). They were born at a mean GA of 28.4 GA ± 2.6; 87 were males and 80 were females. Mean birth weight was 1.110 kg (SD ± 0.4 kg); at 6 months our infants had a mean weight of 6.850 kg (SD ± 1.08 kg), and at 1 year of CA a mean weight of 8.81 kg (SD ± 1.29 kg). At birth, 19.2% were <10th percentile and the rate increased to 61.1% at discharge and decreased to 31.7% at 6 and 12 months of CA. Table 1 reports also the percentage of newborns with head circumference and total length below the 10th percentile at birth, discharge, and at 6 and 12 months of CA. The delta *Z*-score from birth to 1 year of CA was −0.93 ± 1.5 for weight, 0.02 ± 1.7 for head circumference, and 0.59 ± 1.5 for length, respectively.

At discharge, 58% of the babies were fed their own mother's milk (OMM), exclusively in 35%, and 42% were fed formula milk. All children were discharged with vitamin D and iron supplementation. Considering all the PIs, they were fed OMM for a median period of 63 days (interquartile range [IQR]: 19–134) during the first year of life. At the beginning of CF, 8% still consumed exclusive OMM, 8% consumed formula and OMM, and the remaining only formula. PIs started CF at a mean of 7 (±1.9) months of chronological age and 4.5 (±1.4) months of CA. CF was introduced in 67% of our infants between 5 and 8 months of chronological age. CF started after 8 months of chronological age in 23% of our PIs and in 10% before 5 months of chronological age; in 10% of cases, we found an early onset of CF (before 3 months of CA). The first food introduced was fruit in 82% (*n* = 136), while in 13% it was rice flour in vegetable broth (*n* = 22). Other foods were introduced in 5% of cases, such as vegetable broth only or cornmeal-tapioca in vegetable broth. The first milk-based meal replaced by CF was the mid-morning or afternoon feed in 76.1% of cases (43.4% and 32.7%, respectively). The recorded data allowed us to evaluate the introduction times of the various foods (average standard deviation, minimum and maximum age, and CA) (Table 2).

TABLE 2 Food insertion timing with complementary feeding (*n* = 167).

	Mean	SD	Min–max
Creams gluten-free			
Chronological age	8.1	2.2	4.5–20.1
Corrected age	5.3	1.8	1.5–17.2
Pasta			
Chronological age	10.3	2	6.2–17.9
Corrected age	7.7	1.9	3.8–14.2
Meat			
Chronological age	8.6	2.3	4.7–20.3
Corrected age	5.9	1.8	1.9–17.3
Fish			
Chronological age	9.8	2.5	5.6–20.9
Corrected age	7.1	2.2	2.9–17.8
Eggs			
Chronological age	11.8	2.3	7.5–18.3
Corrected age	9.2	2.2	4.8–15.7
Legumes			
Chronological age	10.8	2.9	5.8–23.5
Corrected age	8	2.5	3.6–20.1
Aged cheese			
Chronological age	8.1	1.9	4.7–18.1
Corrected age	5.4	1.4	1.9–9.5
Fresh dairy products			
Chronological age	9.5	2.5	4.6–20.9
Corrected age	6.8	2.2	1.5–18.6
Fruit			
Chronological age	7.5	2.2	3.9–19.6
Corrected age	4.7	1.7	1–16.9

Note: Insertion times of the various foods, expressed in months (mean, standard deviation, range maximum–minimum).

Regarding possible errors during CF, the collected data show that 17.4% (*n* = 29) consumed sweet drinks and salt was added to baby food in 33.5% of cases (*n* = 56), while in 12.6% (*n* = 21) stock cubes were used.

Regarding fluid intake, 46.1% of the children drank only mineral water (*n* = 77), while 53.9% also consumed other drinks (i.e., chamomile tea, orange juice, or other fruit juices).

From the 24-h dietary recall, it was possible to estimate energy intakes and macro- and micronutrients at 1 year of CA (Table 3). PIs introduced a mean of 300 kcal/die extra compared to the theoretical energy requirements, with an average intake at 1 year of CA of 121 ± 31 kcal/kg/day. In the sample examined, protein intake was also higher than recommended, with an average intake of 39 ± 11 g/day. Regarding the other macronutrients, the intake of both total lipids and carbohydrates was slightly lower than recommended.

Other micronutrients like sodium, potassium, calcium, and phosphorus were higher than recommended (see Table 3). Notably, 95.2% of our PIs consumed aged (or seasoned) cheese every day, and 85% of our PIs consumed processed meat (i.e., cooked ham) at least once a week (data not shown). Vitamins were adequate, except for vitamin D. With CF our previous PIs received an average of 4 µg of vitamin D per day at 12 months of CA. Daily requirements were ensured by vitamin D supplementation in 84.4% of our sample (average of 14 µg).

In a subgroup of infants for whom we evaluated bone status with ultrasound during hospitalization, we also measured bone ultrasound at 1 year of CA (Table 4). Regarding bone status, 10% of our sample ($n = 5$) had MBD at birth, 24% ($n = 12$) at hospital discharge, and 28% ($n = 14$) at 1 year of CA.

We did not find statistically significant correlations between macronutrient and micronutrient intakes and growth or bone status at 1 year of CA. However, we

TABLE 3 Theoretical needs (LARN 2014) and estimated intake with complementary feeding ($n = 167$).

	LARN 2014 needs 6–12 months	Estimated intake mean ± SD
Energy intake		
(kcal)	717.1 ± 190.1	1.028.4 ± 224.6
(kcal/kg)		121 ± 31
Proteins		
(g)	11.4 ± 2.3	39.3 ± 11
(%)	6.4 ± 1.3	15.3 ± 3.2
Total fats (% kcal)	40	38 ± 6
Total carbohydrates (% kcal)	55	45 ± 7
Sodium (mg)	400	767 ± 524
Potassium (mg)	700	1366 ± 507
Iron (mg)	8	19 ± 100
Calcium (mg)	260	824 ± 525
Phosphorus (mg)	275	690 ± 262
Zinc (mg)	3	8 ± 14
Vitamin B1 (mg)	0.3	0.7 ± 0.3
Vitamin B2 (mg)	0.4	1.4 ± 0.8
Vitamin B3 (mg)	5	9 ± 4
Vitamin B6 (mg)	0.4	1.6 ± 1.8
Vitamin A (µg of retinol equivalent)	450	632 ± 372
Vitamin C (mg)	35	88 ± 49
Vitamin D (µg)	10	4 ± 4
Vitamin E (mg of α-tocopherol)	4	9 ± 12
Folic acid (µg)	110	163 ± 78

Note: Comparison between theoretical needs in the first year of life and estimated intakes in our babies at 1 year of CA.

Abbreviation: CA, corrected age.

TABLE 4 Bone status (QUS parameters) ($n = 50$).

	Birth	Hospital discharge	Corrected age 12 months
mc-BTT (μs)	0.50 ± 0.1	0.53 ± 0.1	0.83 ± 0.2
Z-BTT length	−0.2 ± 1.6	−1.5 ± 1.0	−1.24 ± 2.7

Note: Values of mc-SOS and mc-BTT (mean and SD) at birth, discharge, and at 12 months of CA.

Abbreviations: CA, corrected age; mc-BTT, metacarpus bone transmission time; QUS, quantitative ultrasound; Z-BTT, bone transmission time Z score.

found a correlation between vitamin D intakes provided by the diet and bone parameters (mc-BTT: $r = 0.36$, $p = 0.01$) at 1 year of CA.

4 | DISCUSSION

The goal of early feeding is to promote the growth potential of PIs[1] despite the lack of nutrient accumulation that normally occurs in the last trimester of pregnancy.[3,28] PIs have specific nutritional needs possibly different from those of full-term newborns[8] and the most appropriate time for introducing solid foods to PIs is still a matter of debate.

CF was initiated in our children at a mean chronological age of 7 months (4.5 of CA), with notable differences in its starting. It is known that PIs are usually weaned earlier than their full-term counterparts[12] and a great heterogeneity in the initiation of CF in PIs was detected[15] possibly due to the differences in the neurological, auxological developmental times, and on GA at birth.[7,29]

CF in PIs should begin between 5 and 8 months of chronological age (3 months of CA),[8] when some of the neurological abilities are achieved (adequate neck control and disappearance of tongue's protrusion reflex)[8] providing also human or formula milk during CF. One can notice that only 16% of the cases were still breastfed at the start of the CF and 84% of cases consumed only formula milk, though human milk is recommended during CF.[30] Also PIs should be breastfed if discharged with an appropriate weight for GA while, if underweight for GA, they should continue to receive fortified human milk.[3,31] Surprisingly, there are no specific recommendations regarding the type, sequence, and rate of introduction of CF for PIs, so guidelines for full-term infants remain the gold standard.[11,32] In our sample, we found that low-calorie foods such as homogenized or grated fruit were the first food offered in 82% of cases as already reported.[33] Nonetheless our PIs introduced a mean of 300 kcal/die extra compared to the theoretical energy requirement.[21] Consequently, it is essential to counterbalance in PIs the risk of poor growth with the potential risks of an increased energy intake and consequent overgrowth.[34]

Our children had an average protein intake of 39.3 ± 11 g of protein per day instead of 11.4 ± 2.3 g as recommended.[21,35] As already outlined, a rapid increase in protein intake was reported during CF and the transition to the familiar diet, and it was associated with unfavorable body composition in child and adolescence.[36] In fact, elevated protein intakes are linked to a rapid weight gain and higher concentrations of hormones (insulin, insulin growth factor-1) involved in enhanced tissue accumulation and increased risk of overweight/obesity later in life.[36] Protein intakes in PIs should be strictly monitored since low birth weight and successive overgrowth can be considered as an independent risk factor for chronic noncommunicable diseases later in life.[37] In particular, infants who have experienced a phase of rapid postnatal growth recovery after a period of relative delay[38] should be carefully monitored, as this condition can lead to the development of metabolic syndrome later in life.[39]

As it is reported in the literature, a relevant percentage of PIs are still growth restricted in the first years of life[40] and specifically 36% of our population were still <10th percentile at 1 year of CA, while 2.4% had a weight >90th percentile.

In our population weight is more affected than length or head circumference already at the time of hospital discharge and this gap maintains during the first year of life. A possible explanation for this phenomenon could be that weight suffered most of the restriction to preserve the other anthropometric measures, especially head circumference, as it happens with the pattern of the late intrauterine growth restriction and the phenomenon of "head sparing." We can find similar concepts in the literature where it was reported that the *Z*-score of head circumference was the most preserved in preterm born infants.[40]

Unfortunately, we did not follow up our PIs further to understand if they later improved their weight and we did not have data on body composition and consequently on quality of growth.

We also found that 17.4% of our children ate sugary drinks, a practice to avoid since it is related to excessive energy intake and the development of chronic noncommunicable diseases.[41]

We have found an excessive micronutrient (Ca/P/Na/K) intake during CF in our PIs, due to uncorrected habits such as adding salt to the baby food or consuming excessive processed or seasoned food. Concerning sodium, a high-salt diet in childhood appears to lead to increased cardiovascular risk and to influence the preference for excessive salt consumption in adulthood,[42] a relevant finding since several studies have shown the correlation between low birth weight and high blood pressure since childhood.[43] In our population, vitamins and minerals intakes were adequate and vitamin D was ensured by supplementation.[44,45] However, it can be observed that infants not receiving vitamin D supplementation did not meet the suggested requirements. This is particularly important since vitamin D has effects not only on bone growth and mineralization but provides benefits for overall health[45,46] and it is known that PIs are at risk of depletion[44,47] and of MBD,[23,27] which was still detected in 28% of examined PIs at 1 year of CA. Furthermore, we found a correlation between vitamin D intakes provided by the diet and bone parameters (mc-BTT: $r = 0.36$, $p = 0.01$) at the same age. A higher calcium and phosphorus dietary intake was detected in our children; nonetheless, a recent review argues that the current recommendations could underestimate these needs in PIs.[47]

Our study has some limitations: first, we did not collect data beyond the first year of CA and on neurodevelopment. Second, the small sample of children evaluated with QUS does not allow us to define the possible influences of nutrition on bone status.

In conclusion, our population of PIs started on average CF in agreement with current suggestions, although with a great heterogeneity, with low-caloric food and some mistakes (sugar introduction, excessive protein intake). Vitamin D was ensured by supplementation; interestingly, vitamin D provided by the diet correlated with bone status at 1 year of CA.

Our results suggest that nutrition in PIs during CF needs to be strictly monitored; additional studies with a larger sample are necessary to investigate the possible influences of nutrition in this period of life on further growth and bone status.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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