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Megan Van Hoorn

Sarah Staskiewicz

Mary B. Feuling

Stephanie Pladies

See next page for additional authors

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Authors

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Texture Consumption Patterns of 8- to 12-Month-Old Infants: A Reflection of Typical Feeding Development

Amy L. Delaney

Department of Speech Pathology and Audiology, Marquette University, Milwaukee, WI

Megan Van Hoorn

Department of Clinical Nutrition, Children's Wisconsin, Milwaukee, WI

Sarah Staskiewicz

Sarah Staskiewicz Nutrition, LLC, Verona, NJ

Mary Beth Feuling

Department of Clinical Nutrition, Children's Wisconsin, Milwaukee, WI

Stephanie Pladies

Monroe Carell Jr. Children's Hospital at Vanderbilt, Nashville, TN

Naveen K. Bansal

Department of Mathematics, Statistics and Computer Science, Marquette University, Milwaukee, WI

Praveen S. Goday

Division of Pediatric Gastroenterology and Nutrition, Medical College of Wisconsin, Milwaukee, WI

Abstract

Purpose: The lack of age-appropriate expectations for the acquisition of feeding skills and consumption of textured food in early childhood inhibits early and accurate identification of developmental delay in feeding and pediatric feeding disorder. The objective of this study was to describe texture intake patterns in a cohort of typically developing infants between 8 and 12 months of age, with the aim of informing future research to establish targets for feeding skill acquisition. **Method:** Using cross-sectional methodology, we studied the presence of liquid and solid textures and drinking methods in the diet, consumption patterns by texture and drinking methods, and caloric intake by texture via caregiver questionnaire and 3-day dietary intake record in 63 healthy infants between 8 and 12 months of age. Descriptive statistics and a one-way analysis of variance were conducted to compare the effect of age on texture intake patterns. **Results:** Findings reveal rapid advancement of intake patterns for texture overall and for energy intake by texture between 8 and 12 months of age. Whereas liquids continue to provide a large proportion of total energy through this time, solids contribute an equal proportion of energy by 12 months of age. **Conclusions:** This study describes texture intake patterns in a cohort of typically developing infants between 8 and 12 months of age by examining the presence of texture and drinking methods, liquid and solid consumption patterns, and energy intake by texture. When applied to data from a future population sample, findings will provide a threshold for age expectations for typical and disordered feeding development to aid in the detection of developmental delay in feeding and pediatric feeding disorder.

Headnote

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Method: Using cross-sectional methodology, we studied the presence of liquid and solid textures and drinking methods in the diet, consumption patterns by texture and drinking methods, and caloric intake by texture via caregiver questionnaire and 3-day dietary intake record in 63 healthy infants between 8 and 12 months of age. Descriptive statistics and a one-way analysis of variance were conducted to compare the effect of age on texture intake patterns.

Results: Findings reveal rapid advancement of intake patterns for texture overall and for energy intake by texture between 8 and 12 months of age. Whereas liquids continue to provide a large proportion of total energy through this time, solids contribute an equal proportion of energy by 12 months of age.

Conclusions: This study describes texture intake patterns in a cohort of typically developing infants between 8 and 12 months of age by examining the presence of texture and drinking methods, liquid and solid consumption patterns, and energy intake by texture. When applied to data from a future population sample, findings will provide a threshold for age expectations for typical and disordered feeding development to aid in the detection of developmental delay in feeding and pediatric feeding disorder.

What Is Known:

- * Expectations regarding early feeding development have been focused on nutrition parameters.
- * Lack of standardized, age-appropriate expectations for texture progression in infancy and early childhood inhibits early and accurate identification and treatment of feeding disorder.

What Is New:

- * We have described changes in dietary composition by texture and drinking method in healthy infants.
- * Together with nutritional composition, this study describes a more comprehensive assessment of infant feeding, particularly to clinicians who need to diagnose feeding skill deficits.

Supporting the development of oral feeding skills is dependent on the safe and timely exposure to new food textures in concert with developmental ability and proactively responding to changing nutrient requirements. Parents, caregivers, and clinicians must attempt to align evolving feeding skills with the introduction of specific textures to prompt ongoing skill development (Gisel, 1991; Green et al., 2017). The profoundly dynamic nature of the development of the oral, gross, and fine motor skills required for successful feeding necessitates ongoing oversight and reassessment to guide the infant's feeding journey (Birch & Doub, 2014; Delaney & Arvedson, 2008).

Although typically developing infants are born with the physiological ability to consume adequate liquid textures to sustain health (i.e., breast milk and/or formula), a successful introduction and acceptance of advanced textures depends on the maturation and coordination of highly complex oral sensorimotor skills (Arvedson & Lefton-Greif, 1996; Delaney & Arvedson, 2008), a process that is subject to interference when developmental and/or medical issues arise (Goday et al., 2019). Criteria that define age-appropriate oral intake of various textures are necessary for the successful identification of infants and children who may not be following the expected trajectory of feeding advancement. Furthermore, age-appropriate norms are needed to facilitate the effective utilization of diagnostic criteria for pediatric feeding disorder (PFD). Unlike growth and nutrient intake targets that have established standards (Butte, 2006; Institute of Medicine, Food and Nutrition Board, 2000), the lack of evidence-based expectations for texture consumption by age in infancy and early childhood can inhibit early and accurate identification and treatment of feeding disorders.

A high prevalence of feeding disorder exists in children under the age of 5 years: Kovacic et al. (2021) report between one in 23 and one in 37 of children in this age group are diagnosed with feeding disorders per International Classification of Disease, Ninth Revision and International Classification of Disease, Tenth Revision coding. Recently, a consensus definition and conceptual framework was established for PFD, a unifying diagnostic term defined as "impaired oral intake that is not age-appropriate, and is associated with medical, nutritional, feeding skill and/or psychosocial dysfunction" (Goday et al., 2019). According to Goday et al. (2019), feeding skill function is a measure of texture progression, feeding position and use of equipment during intake, and whether modified feeding strategies are employed during feeding; these factors are to be considered in the context of oral sensorimotor and pharyngeal functioning. Thus, criteria for age-appropriate intake must include textures of food and positioning, seating, and method of intake, alongside whether specific strategies are required for safe and efficient oral intake (Goday et al., 2019).

In outlining an assessment of age-related texture intake patterns, one must also consider other key areas related to the multidimensional aspects of feeding: nutrient intake guidelines and feeding skill norms (Carruth & Skinner, 2002; Delaney & Arvedson, 2008; Evans Morris & Dunn Klein, 2000; Gisel, 1991; Le Révérend et al., 2014). Traditionally, feeding guidelines have been focused on nutrition parameters and descriptions of changes in food intake patterns (American Academy of Pediatrics Committee on Nutrition, 2014; Fewtrell et al., 2017; World Health Organization [WHO], 2001). Current guidelines address the presence and duration of breastfeeding, age of onset of complementary feeding, feeding frequency, and the presence and proportion of

energy intake by food groups and nutrients (American Academy of Pediatrics Committee on Nutrition, 2014; Fewtrell et al., 2017). However, changes in nutrient requirements occur in parallel to changes in feeding skill function during the first few years of life, and oral-motor development is required to support the consumption of adequate age-appropriate food for healthy growth and development. Thus, associating nutrition intake and texture acceptance is necessary to provide meaningful insights into age-dependent expectations for feeding skill development.

In several studies, food intake patterns have been robustly measured for exposure to and presence of new food, the frequency of consumption of food, the number of different food, and energy intake by food groups (Concina et al., 2018; Demonteil et al., 2018; Grummer-Strawn et al., 2008; Kudlova & Rames, 2007; Reidy et al., 2017). These analyses of age-specific food intake patterns present an opportunity to further develop feeding expectations by which to compare children learning and struggling to eat. Guidance on the types of food an infant or child should consume at any given feeding stage must be driven by feeding skills that are expected to be present (Delaney & Arvedson, 2008).

The role of texture in food acceptance and feeding skill development has been observed. In a group of 32 children with a mean age of 39 months, texture modification was observed as a significant influencer of food acceptance, more than taste ($p < .001$) or color ($p < .01$) modification (Werthmann et al., 2015). A randomized controlled trial provided evidence that exposure to texture at 8 months of age can impact the development of chewing skills (da Costa et al., 2017). Furthermore, the timing of introduction of more advanced textures has been associated with a later risk of picky eating; evidence suggests there are ideal windows of time in which to begin to expose infants to more complex textures, and failing to do so has implications that can persist later into childhood (Coulthard et al., 2009; Emmett et al., 2018; Northstone et al., 2001). Two studies have highlighted a "sensitive period" for texture acceptance and skill development may be around 9 months of age (Coulthard et al., 2009; Emmett et al., 2018). Although an essential insight into the dynamics of feeding skill development and food acceptance, identification of "sensitive periods" in the feeding journey is only a preliminary step in providing more robust recommendations around feeding milestones.

More recently, analysis of exposure to various food textures has been incorporated into studies evaluating food consumption patterns during the complementary feeding stage. However, categorization of food by texture is often dichotomously labeled as either liquids or solids (Grummer-Strawn et al., 2008). Some studies distinguish semisolids or soft and hard solids (Kudlova & Rames, 2007; Reidy et al., 2017). Primary analyses include the presence of texture and the frequency of consumption by age, such as solid (nonliquid) food within different food groups (Grummer-Strawn et al., 2008), the number of solid food consumed per day (Kudlova & Rames, 2007), and the frequency of consumption of food by texture (Demonteil et al., 2018; Kudlova & Rames, 2007). Data available to date do not allow for prescriptive guidelines for age-appropriate texture exposure throughout the feeding journey.

Criteria that define age-appropriate texture intake patterns are necessary to serve as a clinical reference in the comparison of children presenting with differences in feeding development to meet diagnostic criteria for PFD. Exploring these additional variables could lead to a comprehensive methodology as the first step in quantifying age-appropriate feeding skill expectations for the application of PFD diagnostic criteria. Identifying feeding disorder and potential nutritional risk at the earliest age could facilitate intervention and reduce the chronic nature of feeding problems, thereby improving developmental and nutrition-related outcomes. A comprehensive assessment of texture intake patterns should include several important elements in early feeding: food texture exposure, feeding and food intake patterns, and nutrient intake guidelines.

Therefore, the objective of this study was to describe texture intake patterns in a cohort of typically developing infants between 8 and 12 months of age via the presence of texture and drinking methods, liquid and solid

consumption patterns, and energy intake by texture, with the aim of informing future research that will develop a normative standard for age-appropriate oral intake.

Method

Study Population and Design

This investigation employed cross-sectional methodology to examine feeding practices of infants from three target age groups: 8, 10, and 12 months of age. To reduce performance variability, the age range of eligible subjects was limited to ± 2 weeks from the target age in months (i.e., 8 months ± 2 weeks, etc.). Based on power analysis, 21 children were recruited for each age group, for a total of 63 children. The study was approved by the institutional review board at Marquette University.

Recruitment

This study was part of a larger investigation of oral feeding skill development that included videotaping children during a feeding observation. Participants were recruited through community-wide flyers placed at day care centers, local pediatrician offices, and child-friendly locations such as "Mommy and Me" classes throughout southern Wisconsin. Interested caregivers were instructed to contact the principal investigator (PI; A.L.D.) for a screening interview. The interview-lasting up to 30 min-was conducted via phone to determine eligibility.

Inclusion/Exclusion Criteria

Eligibility was determined based on the initial screening phone interview and a child's score on the Communication and Symbolic Behavioral Scales (CSBS) Infant-Toddler Checklist (Wetherby et al., 2002). Initial eligibility required that participants were born at full-term gestation (i.e., > 37 weeks post-conceptual age), determined to be at > 5 th percentile (z score of -1.645) for birth weight on the WHO growth chart and following a weight gain trajectory of > 5 th percentile at the time of study enrollment and 3 months poststudy, without known medical diagnoses, progressing in feeding without pediatrician or caregiver concern and had a minimum of 2 weeks since introduction of solid food (nonliquid), and typically developing without a history of or current enrollment in developmental therapies or pediatrician or caregiver concern for development.

If the child met initial inclusion criteria, the caregiver was mailed the CSBS for a formal screening of communication. Final eligibility was confirmed if the child received a total standard score of 85 or greater (-1 SD or less below the mean) on the CSBS. The CSBS was determined to be an accurate tool for screening for this study due to its predictive validity of prelinguistic skills and later language outcomes (Eadie et al., 2010). Since normal communication development is reliant on the interplay of motor, cognitive, sensory, and linguistic skills (Nip et al., 2011), it was determined that a communication screener would be a more effective means to capture subtle differences in development compared to screening for motor skill delays, especially since not all delays are visibly overt. The CSBS, in combination with other inclusion criteria of pediatrician screening, lack of caregiver concerns, and lack of developmental therapy, was deemed to sufficiently identify typically developing children. Enrollment was confirmed with caregivers via e-mail. Poststudy eligibility was determined based on confirmation that the child was continuing to meet growth trajectory criteria.

Children were excluded from the study if they did not meet inclusion criteria, failed the initial eligibility screening interview, had a known medical diagnosis, were enrolled in developmental therapy to address developmental concern, or did not meet scoring criteria for the CSBS. Excluded children were referred to their pediatrician to discuss concerns.

Participation in the study required the caregiver to complete all study materials and return them to the PI according to the study timeline. Participants received a gift card or toy/book equal to \$10.

Data Collection

Caregivers of enrolled children received a packet in the mail with all study materials, including the participant informed consent form, feeding instructions, a 3-day dietary intake record, and the Developmental Questionnaire (see Supplemental Material S1). The Developmental Questionnaire was developed based on factors relevant to typical feeding development as reported in the literature (Carruth & Skinner, 2002; Delaney & Arvedson, 2008; Evans Morris & Dunn Klein, 2000; Gisel, 1991; Le Révérend et al., 2014). Caregivers completed the dietary intake record and the Developmental Questionnaire prospectively according to the instructions provided. The data were collected by the child's caregiver, in either the child's home or day care setting, depending on the caregiver preference.

Presence of Texture and Drinking Method

To assess the presence of different textures and drinking methods within the child's diet, as well as related developmental milestones, caregivers completed a questionnaire created for this study. Caregivers reported details on developmental milestones and feeding history on the questionnaire. For development, the age of onset of general gross motor and communication milestones and oral sensory presentation were reported. For feeding, the age of introduction of various complementary food, textures, and cup drinking; feeding behaviors; current presence or absence of various textures and drinking methods in the child's diet; and daily frequency with which each texture and drinking method were offered was captured.

For the purposes of documenting the first exposures to food and textures that typically appear early in the complementary feeding period, a list of select food/textures (i.e., infant cereal by spoon, pureed fruits/vegetables, and finger food) was provided for the caregiver to indicate the age of introduction. For all other outcomes being measured, the textures of interest included liquids (expressed breast milk, formula, milk, water, and juice), purees (smooth purees, textured purees, and adult purees [i.e., pureed food often maintained into adulthood such as yogurt and applesauce]), and solids. Solids were further differentiated as either easily dissolvable (e.g., crackers that dissolve with saliva), soft/well cooked, crunchy, or regular (i.e., regular table food provided without modification). Drinking methods included breast, bottle, and cup (i.e., sipper cup [not spill proof], sipper cup with valve [spill proof], open/regular cup, and straw). Full details of the Developmental Questionnaire can be found in Supplemental Material S1.

Consumption Patterns

Caregivers prospectively completed a dietary intake record (Livingstone et al., 2004) tracking three consecutive days of feedings. Caregivers recorded the start and end time of each feeding opportunity (i.e., meals, snacks, breast, or bottle feeding), each liquid or food offered, and an estimated amount consumed for each. Consumption of each liquid and food item was estimated based on the number of bites of the food eaten, liquid fluid ounces consumed, or an approximate amount of food or liquid consumed based on comparison to a standard measuring cup. Breastfeeding was recorded by the start and end time of the feeding opportunity.

Energy Consumption

Each food and liquid item on subjects' dietary intake records was entered into Nutritionist Pro nutrient analysis software (Nutritionist Pro, n.d.). The energy content of certain food was ascertained through the U.S. Department of Agriculture (n.d.) food composition database and brand-specific websites.

Data Analysis

Texture Coding

Each item on the 3-day dietary intake record was coded by the PI (A.L.D.) as liquid, puree, dissolvable solid, or regular solid texture; drinking method (breast, bottle, or cup); and volume by each texture.

Statistical Analyses

Descriptive data were generated for chronological ages and age at introduction of food textures. To assess the presence of different textures and drinking methods within the infant diet, group means were taken within each of the three age groups to describe the presence of each texture and drinking method. Texture consumption patterns were determined by the proportion of meals each texture was present; the consumption of texture at each meal was averaged across the 3-day dietary intake record. A one-way between-subjects analysis of variance (ANOVA) was conducted to compare the effect of age on feeding frequency, proportion of meals that the various textures and drinking methods were present, and the number of unique food items by texture offered. Post hoc analysis using Tukey's honestly significant difference (HSD) test was used to determine age-specific differences in performance. A p value of $< .05$ was considered as a statistically significant effect.

Analysis of the overall contribution to daily energy intake by different textures was conducted using Nutritionist Pro. The quantity of energy consumption by texture was averaged across the 3-day dietary intake record for each participant. Distribution of energy analyses excluded children who fed directly at the breast.

Results

Subject Characteristics

Sixty-three children-21 per age group-met inclusion criteria and were enrolled in the study. Sex and age characteristics of each age group were as follows: 8 months: 52% male ($n = 11$), chronological age ($M \pm SD$) = 31.8 ± 1.37 weeks; 10 months: 52% male ($n = 11$), chronological age = 39.8 ± 1.37 weeks; and 12 months: 33% male ($n = 7$), chronological age = 47.6 ± 1.12 weeks. All children had weights > 5 th percentile (z score of -1.645) for age at all three time points required for inclusion in the study. Sixty-two children (98%) were White/Caucasian, and one child (2%) was Black. All the participants' mothers were White/ Caucasian. Maternal education level was high in this cohort, with 62 of 63 (98%) of the participants' mothers having received a college education. Of note, one caregiver indicated that they were utilizing a baby-led weaning approach, in addition to traditional spoon feeding.

Timing of Texture and Cup Introduction

A total of 58 caregivers provided data on the timing of texture and cup introduction: $n = 20$ for 8 months, $n = 18$ for 10 months, and $n = 20$ for 12 months. Participants' ages when textures and cup drinking were introduced are summarized in Table 1. In this cohort, the introduction of texture began at approximately 4.4 months of age via infant cereal, then progressed through pureed fruits and vegetables, other smooth purees, then lumpy/textured purees over the next 3-3.5 months. The mean ($\pm SD$) age of introduction of dissolvable solids (i.e., food that melts in the mouth with minimal chewing such as "puffs," graham crackers, butter crackers) was between $7.4 (\pm 1.02)$ and $8.2 (\pm 1.59)$ months, which was similar to the mean age of introduction of lumpy/textured purees, between $7.4 (\pm 1.01)$ and $7.9 (\pm 1.33)$ months. The introduction to cup drinking varied from a mean age of $6.7 (\pm 1.46)$ to $9.0 (\pm 2.07)$ months, the widest range of age of introduction for the feeding milestones captured in this study.

Due to the subjectivity involved in the caregiver reported data and the lack of standardized texture categories available and to ensure accurate and consistent coding across the data set, the more detailed categories initially used to document the presence or absence of various textures or drinking methods in the child's current diet (see Developmental Questionnaire in Supplemental Material S1) were simplified for coding and data analysis. Textures were grouped into three main categories: liquids (e.g., free flowing consistency such as breast milk, formula, or water), purees (e.g., cohesive semisolid that requires no chewing such as smooth or blended food), and solids (e.g., nonliquid consistency that requires varying levels of chewing). Two subcategories were maintained for the solid category: dissolvable and regular solids. Drinking methods were collapsed into three

categories, including breast (putting infant to breast), bottle (any type of infant bottle), and cup (sipper cup [not spill-proof], sipper cup with valve [spill proof], open/ regular cup, or straw).

Presence of Texture and Drinking Method

A total of 63 caregivers provided information on the presence of various textures and drinking methods, $n = 21$ for each age group. Liquid texture was maintained in the diet across all age groups. Pureed textures were dominant across age groups, appearing in 100% of the diets of 8-month-olds and between 86% and 90% of the diets of 10- and 12-month-olds. Fifteen percent of 8-month-olds had no solid textures in the diet; all 10- and 12-month-olds' diets did include solid food. The presence of dissolvable solids remained high and mostly unchanged between 8 and 12 months. As expected, there was a dramatic increase in the presence of regular solid food between 8 and 10 months of age (see Table 2). More than nine out of 10 children had some regular solid food in their diet at 10 months of age. For drinking method, breastfeeding was present for about half of children at both 8 and 10 months of age but declined to 15% by the first birthday. Conversely, bottle feeding was maintained at a much higher percentage at 12 months of age, appearing for 75% of participants. Most children drank from a cup, particularly the sipper cup, with limited presence of an open cup and straw. Nearly all children used a combination of drinking methods. Table 2 summarizes the presence of drinking methods and textures across the participants.

Consumption Patterns

A total of 42 3-day dietary intake records were collected ($n = 17$ for 8 months, $n = 13$ for 10 months, and $n = 13$ for 12 months). There was a statistically significant difference between group means as determined by a one-way between-subjects ANOVA for the number of feedings per day, $F(2, 40) = 4.109$, $p = .024$; the number of liquid-only feedings per day, $F(2, 40) = 6.734$, $p = .003$; the frequency of cup usage, $F(2, 40) = 6.334$, $p = .004$; the proportion of meal purees, $F(2, 40) = 10.98$, $p < .001$, and regular solids, $F(2, 40) = 23.871$, $p < .001$, present; and the variety of food for purees, $F(2, 40) = 5.662$, $p < .007$, dissolvable solids, $F(2, 40) = 4.546$, $p < .017$, and regular solids, $F(2, 40) = 24.733$, $p < .001$, as shown in Table 3.

Post hoc comparisons using Tukey's HSD test revealed specific age differences. The average number of feedings per day was significantly lower at 12 months of age than at 8 and 10 months of age ($p < .024$). As expected, the average number of pureed feedings decreased from 8 months (2.7) to 12 months (1.5) of age, whereas the average number of solid feedings increased over the same time frame (0.7-2.7, $p < .001$). The proportion of meals when liquids were present did not significantly differ by age, but the average number of liquid-only feedings (i.e., entire meal consisting of a liquid) was significantly different between 8 and 12 months. Overall, the number of feedings per day declined from about seven at 8 and 10 months of age to five and a half at 1 year of age; most of this change was accounted for by the decrease in liquid-only feedings (see Table 3).

For consumption by texture, as stated above, liquid consumption remained stable as children aged, but there was an expected decline in the number of pureed feedings with a concomitant increase in regular solid food feedings between 8 and 12 months of age. There was no change in the frequency of the presence of dissolvable solids at meal occasions (see Table 3).

There was a statistically significant difference in the average number of cup feedings, increasing from 8 to 10 months and again from 10 to 12 months. There were no statistically significant differences between group means for breast and bottle-feeding frequency, which were constant at about two feedings per day. This occurred alongside increases in the frequency of consumption of liquids by cup, which were significantly different between 8 and 10 months of age and between 8 and 12 months of age ($p = .004$; see Table 3).

For texture variety, post hoc comparisons using Tukey's HSD test revealed specific age differences. As expected, the average number of different purees was higher at 8 months versus 12 months, likely reflecting a greater

reliance on purees at a younger age. The variety of dissolvable solids peaked at 10 months of age. The variety of regular solids increased across the three age groups, reflecting the largest increase in variety of the metrics measured. Overall, the variety of purees consumed decreased with age as the variety of regular solids increased (see Table 3).

Distribution of Energy

In the 27 children who were not directly feeding at the breast at the time of the 3-day dietary intake record completion, the overall daily energy intake average was 377.5 kcal/day (\pm 212.5) at 8 months ($n = 8$, 30% male), 717.1 kcal/day (\pm 441) at 10 months ($n = 8$, 30% male), and 712.5 kcal/day (\pm 522.8) at 12 months ($n = 11$, 40% male). The proportion of energy intake from liquids was essentially unchanged between 8 and 10 months and then declined at 12 months (see Figure 1). At 8 months, liquids and purees almost equally contributed to energy consumption. At 10 months, the amount of energy consumed by purees decreased as solid consumption increased. By 12 months, there was little reliance on purees and a reduction in liquids for energy intake due to a sharp increase in solids. Dissolvable solids contributed a negligible amount of energy at 8 and 10 months of age (see Figure 1).

Consumption of purees primarily consisted of commercial infant cereal and baby food, yogurt, applesauce, and oatmeal. Consumption of dissolvable solids primarily consisted of commercial finger food such as puffs and melts, crackers, and dry cereal. Consumption of solids primarily consisted of canned and fresh fruits (e.g., banana, peach, and pear), canned and cooked vegetables (e.g., peas, green beans, and carrots), processed animal protein (e.g., deli meat, meatballs, and chicken nugget), and food high in starch (e.g., pancakes, waffles, bread, and macaroni and cheese).

Discussion

This study examined feeding patterns in a cohort of typically developing children 8-12 months of age and described texture intake patterns via the presence of texture and drinking methods, food and liquid consumption patterns, and energy intake. We expanded on traditional descriptions of the presence of texture and drinking methods by describing consumption patterns-the number of feedings per day, the proportion of meals with a given texture, and the variety of food within a texture category-and the distribution of energy intake by texture. We quantified the presence and consumption patterns of different textures and drinking methods, assessed the contribution of different textures to energy intake, and described how these factors contribute to changes in the overall feeding schedule. Data gathered can help inform future research that can establish age-appropriate comparison standards for children presenting with differences in feeding development to meet diagnostic criteria for PFD.

As expected, our data demonstrate an inverse relationship between a decreasing presence of purees with an increasing presence of solids as children age. This finding reflects the general progression of textures seen in the literature (Demonteil et al., 2018; Tournier et al., 2021). Puree was largely present in an 8-month-old infant's diet. Although most children in the study had dissolvable solids in their diet, there was a sharp increase from 8 to 10 months of age in exposure to and presence of regular solid food. Our data demonstrate a rapid transition from simple to more complex textures in the latter half of the first year that likely reflects feeding skill acquisition. Appropriately, liquids persisted in the diets of 100% of children in each age group.

The presence of different drinking methods provides insight into breastfeeding rates of the cohort, oral-motor development, and feeding practices (Scarborough et al., 2018). The rate of breastfeeding in our cohort at 8 months was 43%, and the rate at 12 months was 15%. Based on 2017 data from the Centers for Disease Control and Prevention (CDC), U.S. breastfeeding rates were 58% at 6 months of age and 35% at 12 months of age (CDC, 2017). The rate of breastfeeding at 8 months of age in our cohort may align with the CDC's 6-month data;

however our rate at 12 months of age was considerably lower. Although the bottle was offered at least twice per day for all children in the study regardless of age, cup drinking—a more advanced drinking method—did not increase to twice per day until 12 months of age, which may indicate increased oral-motor control for liquid consumption (Scarborough et al., 2018). The sipper cup (or trainer cup) was more prevalent in this cohort than other drinking methods, which may reflect the popularity and/or traditional guidance of offering these cups in infancy, or it could reflect parental preference for a spill proof cup. Nearly all children utilized a combination of drinking methods regardless of age.

Our data also reflect a consolidation of mealtimes between 10 and 12 months of age. At 8 and 10 months of age, children had more frequent feedings with a mean of seven per day. A significant shift occurred between 10 months and the first birthday, with feeding frequency declining to five to six feedings per day; this is attributed to fewer liquid-only feedings. This observation reflects the natural and expected progression to relying less on infant formula and/or breast milk to meet nutritional needs and moving to a more "mature" feeding schedule, with solid textures offered at meals and snacks, in addition to liquids (American Academy of Pediatrics Committee on Nutrition, 2014; Hagan et al., 2017; Reidy et al., 2017). Such a feeding schedule is possible when the child's feeding skills and endurance allow the consumption of more nutrition per feeding. Thus, the feeding schedule is one metric that could help establish expectations for age-specific feeding stages.

Unsurprisingly, there was a significant reduction of the frequency of puree consumption between 8 and 12 months. Purees were offered at most meals at 8 and 10 months of age (31% and 27%, respectively) but were offered less often by the first birthday. We observed the opposite trend in the offering of regular solids, with less than one per day offered at 8 months of age, increasing to two per day at 10 months of age, and offered at nearly three meals per day by the first birthday. We suspect this increase in regular solid offerings was due to successful acceptance of solids by the child and may reflect improved oral-motor coordination, chewing skills, and general feeding development. Although the explanation for the increase in solids is speculative, the authors conjecture this highlights the importance to look beyond the mere presence of a texture in a child's diet. Assessing for the proportion of meals that texture provides may offer a more robust expression of feeding development than the presence of a texture alone.

The dynamic nature of a feeding schedule over the first year of life reflects the ever-present changes in age and ability. More specifically, the presence of textures and drinking methods in the diet provides some reflection of skill development. However, the appearance of a texture does not necessarily equate to the ability to consume that texture efficiently, enough for it to contribute meaningfully to energy or nutrient requirements. The amount that a specific food and/or texture contributes to total nutrient intake may be an underappreciated metric in assessing feeding skill performance. The distribution of energy intake by texture may be a key factor in determining age-appropriate texture intake expectations. In our study, by 8 months of age, purees contributed to nearly half of all energy intake. Although energy requirements were still largely obtained from liquids between 8 and 10 months of age, there was also a decline in the energy obtained from pureed food, which corresponded to the increased number and volume of solid feedings offered to the older infants. By 12 months, an equal proportion of intake from liquids and solids was observed.

The developmental time frame after the onset of complementary feeding includes rapid and frequent transitions in feeding related to the presence of texture, consumption patterns (i.e., frequency and interval of eating occasions) related to texture, method of food consumption, and changes in food and beverage sources that comprise energy intake (American Academy of Pediatrics Committee on Nutrition, 2014; Fewtrell et al., 2017; Hagan et al., 2017; WHO, 2001). Guidance on the types of food an infant or child should consume at any given feeding stage must be driven by feeding skills that are expected to be present. Furthermore, it is vital to consider and emphasize nutrition requirements into texture and feeding skill considerations.

It is of critical importance to understand the progression from first exposure to a complementary food to the solid establishment of more advanced textures with increasing variety and drinking methods. Our data provide a preliminary basis for understanding some of the more subtle, but of vital importance, changes that occur during the feeding journey.

From a cross-sectional view, our data demonstrate age-specific feeding profiles of children in infancy. At 8 months, infants had transitioned to purees, consuming adequate amounts for this new texture to contribute nearly 50% of their energy intake. They continued with seven feedings per day. Cup drinking and regular solids were not a prominent feature of their diet. At 10 months, infants continued with more frequent feedings, but cup drinking and regular solid feedings were a prominent feature of meals during the day. A range of purees and regular solids were consumed. There was equal distribution of energy intake across purees and solids. By 12 months of age, children were largely on a mature feeding schedule with cup and regular solids at meals with a large range of different solid food (see Table 3). Solid food and liquids contributed equal proportions of their energy intake. Given that a PFD is defined according to age-related measures (Goday et al., 2019), it is critically important to have reliable age-based comparison metrics that can identify children with evolving feeding problems based on feeding skill deficits and subsequent delays with texture advancement.

Although broad age ranges for stages of feeding development provide a framework for developmental expectations, we have demonstrated that more discrete changes occur throughout feeding development. In the 6 months following onset of complementary feeding, although presence of textures is important, the frequency by which different textures are consumed may be a more important measure of feeding development. Studying not only the presence of textures in the diet but also consumption patterns of various textures may be a more sensitive assessment of skill development and more useful in distinguishing typical developmental variation. Within the feeding schedule analysis, frequency and volume of texture consumption can provide a measure of age-specific abilities in feeding development as a complement to nutritional assessment. With larger cohorts of children, these proposed feeding stages can be confirmed or revised to reflect critical changes in feeding expectations and provide more discrete guidance for medical professionals and caregivers and form the basis by which PFD can be diagnosed.

Limitations

Potential limitations of this study include the homogeneity of the cohort, which does not account for racial or demographic diversity or socioeconomic status, factors known to influence feeding. In addition, since this is a cross-sectional study, longitudinal changes in individual infants could not be captured. This study also investigated children at broad feeding stages and lacks a wide age range of children to reflect changes across the expanse of feeding development than can only be obtained from a much larger study. In addition, we did not review the dietary recalls with the caregiver, and this may have led to inconsistencies in the data. Furthermore, the Developmental Questionnaire developed for this study was not validated.

A major limitation of this study is the lack of standardized texture categories and definitions that account for oral skill development during the first few years of life. Such standardization is available for adults with dysphagia who have experienced the loss of skill via the International Dysphagia Diet Standardization Initiative (IDDSI; Cichero et al., 2017), but this framework is not intended for use in a scenario where skills are expected to evolve and develop, as is the case in typical early development. Likewise, the food textures and liquid thickness described within the IDDSI framework are based on the objective of providing common terminology of food and drink to improve the safety of individuals with swallowing difficulties. Hence, the purpose and objective of the IDDSI framework is foundationally different from one that would exist for the purposes of guiding texture progression during typical oral-motor development. Indeed, existing systems that attempt to describe and categorize textures relevant to infancy and early childhood vary widely without consistent definitions or criteria.

For the purposes of this study, it was concluded that simplified texture categories were appropriate when exploring texture intake patterns in this cohort. Standardized texture categories, terminology, definitions, and descriptions of oral skills required for successful management of various textures are yet unavailable for use in typically developing infants and children.

Future Studies

In the future, we hope to expand and refine the data set for age and include a comparison population that can help identify children at risk of skill acquisition delay and subsequent PFD. We plan to study children at all ages rather than prescribed age ranges and allow the data to inform us regarding significant changes in feeding development to provide a more sensitive metric for comparison and identify children earlier. We will also study a culturally, ethnically, racially, and socioeconomically diverse cohort of children to understand these impacts on feeding. Children would undergo a global developmental assessment to assess the contribution of communication and motor development on feeding progression. We will investigate maternal stress factors, maternal and family diet, and philosophy on complementary feeding practices-specifically baby-led weaning- to understand the impact of family dynamics on texture intake patterns. These data may also help expand current guidance on complementary feeding to include recommendation on texture exposure and progression. For this exploratory study, we decided to use general, more global categories of textures for the analysis so as to avoid overinterpretation of textures that are not standardized appropriately. Our next step would be to determine a texture framework that can be used with this methodology to describe texture progression in much greater detail with a much larger cohort of children without PFD. Finally, we will examine oral sensorimotor skills required to support success with a variety of food textures and drinking methods.

Author Contributions

Amy L. Delaney: Conceptualization (Lead), Data curation (Lead), Methodology (Lead), Formal analysis (Lead), Writing - original draft (lead), Writing - review & editing (Lead). Megan Van Hoorn: Conceptualization (Lead), Data curation (Equal), Methodology (Equal). Sarah Staskiewicz: Formal analysis (Equal), Methodology (Supporting), Writing - review & editing (Supporting). Mary Beth Feuling: Conceptualization (Supporting), Methodology (Supporting). Stephanie Pladies: Data curation (Supporting). Naveen K. Bansal: Formal analysis (Equal). Praveen S. Goday: Conceptualization (Equal), Formal analysis (Equal), Visualization (Equal), Writing - original draft (Supporting), Writing - review & editing (Equal).

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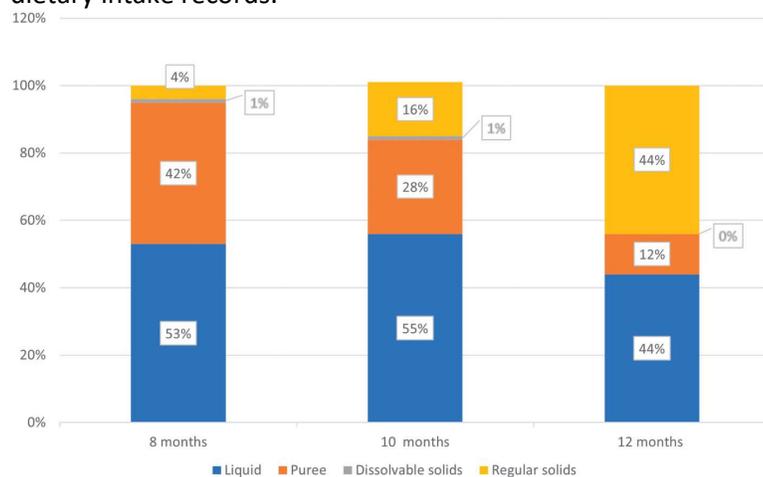
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Figures

Figure 1. Distribution of daily energy intake by texture for nonbreastfed participants ($n = 27$): Means from 3-day dietary intake records.



Tables

Table 1. Age of texture and cup introduction by age in months.

	Age group, <i>M (SD)</i>		
	8 months	10 months	12 months
Texture/method	(<i>n</i> = 20)	(<i>n</i> = 18)	(<i>n</i> = 20)
Puree (cereal) ^a	4.4 (0.65)	4.4 (1.01)	4.4 (1.13)
Puree (Stages 1 and 2) ^{a,b}	5.4 (0.68)	5.3 (1.08)	5.2 (0.9)
Puree (Stage 3 smooth) ^a	6.8 (1.24)	6.7 (1.11)	7.3 (1.44)
Puree (Stage 3 lumpy/textured) ^a	7.5 (1.15)	7.4 (1.01)	7.9 (1.33)
Dissolvable solids ^c	7.4 (1.02)	7.6 (1.03)	8.2 (1.59)
Regular solids ^d	7.9 (1.05)	8.5 (1.07)	9.9 (1.47)
Cup ^e	6.7 (1.46)	7.6 (1.47)	9.0 (2.07)

^aFed by spoon. ^bStages 1 and 2: fruits and vegetables. ^cFinger food. ^dTable food. ^eAny cup.

Table 2. Percentage of children with drinking methods and textures in their diet per parent report.

	Age group, % (<i>n</i>)		
Drinking method and textures	8 months (<i>n</i> = 21)	10 months (<i>n</i> = 21)	12 months (<i>n</i> = 21)
Drinking method			
Breast	43 (9)	53 (11)	15 (3)
Bottle	100 (21)	84 (18)	75 (16)
Cup	81 (17)	100 (21)	100 (21)
Sipper cup (spill proof)	62 (13)	85 (18)	75 (16)
Sipper cup (not spill proof)	33 (7)	35 (7)	45 (9)
Open/regular	24 (5)	30 (6)	35 (7)
Straw	0 (0)	15 (3)	20 (4)
Combination of methods	95 (20)	95 (20)	100 (21)
Liquids	100 (21)	100 (21)	100 (21)
Purees	100 (21)	86 (18)	90 (19)
Solids	86 (18)	100 (21)	100 (21)
Easily dissolvable solids	86 (18)	95 (20)	86 (18)
Regular solids	57 (12)	95 (20)	95 (20)

Table 3. Consumption patterns for meal frequency, drinking methods, and textures in 8- to 12-month-old children: means (standard deviations) from 3-day dietary intake records.

	Age groups							
	8 months		10 months		12 months			
Variable	% Meals	<i>M (SD)</i>	% Meals	<i>M (SD)</i>	% Meals	<i>M (SD)</i>	Comparison ^a	<i>p</i>
Feeding frequency								
Feedings per day		6.9 (1.9)		7.1 (1.5)		5.5 (1.2)	10 > 12	.024
Liquid-only	55	3.8 (1.8)	52	3.7 (1.4)	35	1.9 (1.2)	8 > 12	.003
Breast	25	1.7 (2.2)	20	1.4 (2.0)	5	0.3 (0.6)	n/a	.095
Bottle	36	2.5 (1.6)	32	2.3 (1.6)	42	2.3 (1.5)	n/a	.868
Cup	10	0.7 (0.7)	25	1.8 (1.6)	38	2.1 (1.1)	8 < 10, 8 < 12	.004
Proportion of total meals texture present								
Liquids	71	4.9 (1.6)	76	5.4 (1.8)	82	4.5 (1.2)	n/a	.321
Purees	39	2.7 (0.7)	31	2.2 (0.9)	27	1.5 (0.7)	8 > 12	< .001
Dissolvable solids	14	1 (0.8)	17	1.2 (0.8)	13	0.7 (0.6)	n/a	.215
Regular solids	10	0.7 (0.7)	28	2 (0.9)	49	2.7 (0.8)	8 < 10 < 12	< .001
Number of different food by texture								
Purees		7.4 (3.2)		5.5 (2.6)		3.9 (2.4)	8 > 12	.007
Dissolvable solids		1.5 (1.3)		2.7 (1.6)		1.1 (1.2)	10 > 12	.017
Regular solids		2.2 (2.9)		7.2 (4.4)		14 (6.2)	8 < 12; 10 < 12	< .001

Note. Bold rows indicate significant group differences.

^aBased on Tukey's comparison at familywise error rate of .05.