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Daniels, L, Mallan, KM, Fildes, A orcid.org/0000-0002-5452-2512 et al. (1 more author) (2015) The timing of solid introduction in an 'obesogenic' environment: a narrative review of the evidence and methodological issues. Australian and New Zealand Journal of Public Health, 39 (4). pp. 366-373. ISSN 1326-0200

https://doi.org/10.1111/1753-6405.12376

The timing of solid introduction in an 'obesogenic' environment: a narrative review of the evidence and methodological issues.

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Key words: complementary feeding, developed countries, obesity, narrative review

Running title: The timing of solid introduction in an 'obesogenic' environment

Acknowledgements**:** We wish to thank Ms Lynn Evans Librarian QUT for assistance, Ms Clare Glover for review of abstracts, Dr Seema Mihrshahi for assistance with data extraction and Meat & Livestock Australia for funding support. We also acknowledge the support of the Endeavour Scholarships and Fellowships Programme to Alison Fildes. Dr Kimberley Mallan occupies the Heinz Postdoctoral Research Fellowship funded by H.J. Heinz.

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Potential conflict of interest: None

Abstract

Objective: To evaluate the evidence for association between obesity risk outcomes >12 months of age and timing of solid introduction in healthy term infants in developed countries, the large majority of whom are not exclusively breastfed to 6 months of age.

Methods: Studies included were published 1990-March 2013.

Results: Twenty-six papers with weight status or obesity prevalence outcomes were identified. Studies were predominantly cohort design, most with important methodological limitations. Ten studies reported a positive association. Of these only two were large good quality studies and both examined the outcome of early (<4 months) solid introduction. None of the four good quality studies that directly evaluated current guidelines provided evidence of any clinically relevant protective effect of solid introduction from 4-5 versus ≥ 6 months of age.

Conclusion: Overall the introduction of solids prior to 4 months may result in increased risk of childhood obesity but there is little evidence of adverse weight status outcomes associated with introducing solids at 4-6 rather than at 6 months.

Implications: More and better quality evidence is required to inform guidelines on the 'when, what and how' of complementary feeding.

Introduction

The 2003 WHO recommends that *"infants* should be exclusively breastfed for the first six months *of life. Thereafter….infants should receive nutritionally adequate and safe complementary feeding".*[1] The parallel complementary feeding guidelines are prescriptive in their wording and recommend introducing complementary feeding *"at 6 months (180 days) of age".*[1, 2] The recommendations for exclusive breastfeeding and the timing of solid introduction are inextricably linked because failure to comply with the latter precludes adherence to the former. Thus, it is difficult to determine any potential independent outcomes of introduction of solids prior to 6 months.[3] This circular argument is further complicated by the well-established interactions between exclusive breastfeeding, formula feeding and age of solid introduction and maternal factors such as age, education and smoking.[4-8] The potential for residual confounding is substantial.

The 2003 WHO exclusive breastfeeding recommendations[1] were based on a commissioned Cochrane review first published in 2002 and updated in 2012.[9] The review compared the benefits of exclusive breastfeeding for 6 months versus 3-4 months followed by mixed feeding (breastmilk with formula and/or complementary foods) to 6 months. Of the 23 studies included, 12 were conducted in developed countries. The main findings were that exclusive breastfeeding for 6 months compared to 3-4 months was associated with less gastrointestinal infection (but not hospitalisation for infection). No evidence of deficits in growth or protection against atopic outcomes was reported. Importantly none of the studies distinguished between partial breastfeeding due to introduction of formula versus solids, or adjusted for age of solid introduction. However, a recent RCT from Iceland[10] evaluated exclusive breastfeeding versus breastfeeding plus complementary feeding from four months of age and showed no group difference in total energy intake, growth or body composition at 6 months of age. No other health outcomes were assessed. The overall conclusion of the Cochrane review was that 'the available evidence demonstrates no apparent risks in recommending, as a general policy, exclusive breastfeeding for the first six months of life in both developing and developed-country settings.'[9] The implied risk assessment approach evident in this conclusion and the emphasis on adequate energy, protein and micronutrient intake, energy density, microbiological safety, micronutrient supplementation, active feeding and frequent meals evident in the WHO complementary feeding guidelines[1, 2], suggest a bias towards under-nutrition and a developing country setting. The validity of this one size fits all

approach has been questioned.[11] Despite the high prevalence and important short and long terms adverse outcomes of obesity in developed countries,[12] obesity risk outcomes beyond infancy were not explicitly considered.

Few studies have examined the outcomes of increased duration of exclusive breastfeeding from 3-4 to 6 months in developed countries.[11] Furthermore, there are no data to determine whether the reason for the cessation of exclusive breastfeeding – introduction of formula or solids from 4-6 months - influences outcomes. Results from a large cluster RCT[13] showed no differences in BMI, other indicators of adiposity or blood pressure at 6.5 years of age associated with exclusive breastfeeding for ≥ 3 months or between infants exclusively breastfed ≥ 6 months versus formula from one month. Age of initiation of complementary feeding was not included as a covariate. Analysis of outcomes at 11.5 years further confirmed no longer term effect on overweight or obesity of increased duration of exclusive breastfeeding.[14] A 2007 meta-analysis[15] reported any breastfeeding (i.e. 'ever' or duration) was associated with reduced longer term (age >12 months) risk of established predictors of chronic disease, including obesity, suggesting that these important positive health outcomes are not predicated on exclusive breastfeeding to 6 months. Overall, in the developed country context, the health benefits of exclusive breastfeeding beyond 4 months of age are uncertain.[11] These studies raise questions regarding recommendations for introduction of solids at 6 rather than 4-6 months[1, 2] in developed countries, where over- rather than under-nutrition is a priority child health problem. This is important given that in Australia the prevalence of exclusive breastfeeding to 6 months is only 15% and 35% infants have commenced solids by 4 months of age.[16] This substantial and persistent gap between recommendations/policy and practice has potential implications for the credibility of health workers and self-efficacy of mothers.

A 2010 systematic review[17] examined the relationship between timing of introduction of solids and obesity in childhood and beyond. The review concluded there was no clear prospective association between age of solid introduction and obesity risk. Methodological issues, particularly those related to variable assessment and definitions, were not comprehensively discussed. A 2013 systematic review[18] (published 3 months after our search cut-off date) with stringent selection criteria examined timing of introduction of solid foods on BMI (no self-report data) or percentage body fat between 4-12 years of age. Several studies from countries in nutrition transition e.g. Brazil and India were included. This review

also concluded that overall there was no clear association between age of solid introduction and obesity risk (to 12 years of age) but that very early introduction (age 4 months of earlier) may carry increased risk of childhood overweight.

Our overall intention in this review was to focus on over-nutrition in the context of the contemporary 'obesogenic' environment. Specifically we aimed to take a narrative approach to (i) update and extend the scope of the Moorcroft review[17] through more detailed consideration of the impact on outcomes of variation in exposure comparator groups (e.g. introduction of solids at < 4 versus 4-6 or around 6 months) and treatment of indicators of obesity risk and covariates; (ii) highlight research challenges such as measurement, confounding and reverse causality; and (iii) discuss ethical issues and policy implications for research in this area.

Methods

Databases (Medline, PsycINFO and CINAHL (EBSCOhost), Health & Society (Informit), Scopus, and Web of Science) were searched for English language papers published between 1990 to March 2013. Search terms included 'complementary feeding OR complementary food' OR 'introduction to solids' OR 'infant feeding' OR 'weaning OR weaning foods'. 'Marketing' was used as a search term in Informit only. Filters for humans and infants (e.g. "All infant: birth-23 months" in Medline) were applied. Full text articles were retrieved where abstracts and/or titles appeared to meet the inclusion criteria and reference lists of these papers reviewed to identify any additional potentially relevant studies.

Studies published prior to 1990 were excluded on the basis they predated the dramatic increase in prevalence of childhood obesity[12] and that infant feeding practices and recommendations have changed substantially since that time. Where studies published after this time included older cohorts, this was noted. Only studies of healthy term infants from developing countries were included. The exposure of interest was age of introduction of complementary feeding (solid foods) and there were no restrictions placed on how this was defined. Relevant outcomes included any measure of growth, weight status or obesity risk/prevalence beyond 12 months. This is because differences in early growth related to mode of milk feeding frequently cease to be evident beyond 12 months of age.[19, 20]

In total 664 abstracts and titles were assessed and 166 full text papers were retrieved. Full text papers not retrieved included 247 conducted in non-industrialised countries, 178 that were not relevant to the review, five that reviewed guidelines and one dissertation. Sixty-seven duplicates were removed. Twenty-five studies met the selection criteria. One exception to these criteria was the inclusion of the study by Mehta et al.[21] which provided follow up at 12 months of age but was the only randomised trial. This resulted in inclusion of 26 studies in the review.

Results

Table 1 summarises 26 studies published after 1990 that examine associations between age of solid introduction and indicators of obesity risk or prevalence beyond 12 months of age. This includes nine studies, one case control and seven cohort, published since the Moorcroft searches were completed[17] as well as one 2001 study[22] not included in that review. The table highlights important design and methodological characteristics. Five of the 26 papers, were based on cohorts born in the early 1990s or earlier.[20, 23-26]

Ten studies[22, 25-33] reported a positive relationship. Two of these included older cohorts.[25, 26] One is small and collected data retrospectively from well-baby visit records[31] and another is a small case control study involving children born in the early 2000s in an urban area of China.[33] A further two studies[27, 32] were small (n=210, 307). Hediger et al.[22] conclude a clinically non-significant positive effect. Two large good quality studies[28, 30] reported a positive association between early solid introduction (<3-4 months) and prevalence of overweight at 3-5 years of age. Huh et al.[29] in separate analyses, also showed a strong positive association between introduction < 4 months versus 4-5 months in formula fed but not breastfed infants.

Of the 17 studies (also includes Huh et al.[29] that showed no association[19-21, 23, 24, 29, 34-44], two included only breastfed infants[29, 37], two included exclusively formula-fed infants[21, 43] and four[35, 36, 39, 44] are quality studies with large (> 1000) representative contemporary cohorts and robust multivariable models. The only RCT[21] showed no difference in anthropometrics or body composition at 12 months between infants introduced to solids at 3-4 versus 6 months of age.

Studies that include contemporary cohorts (born after 1990) and a categorical definition of obesity risk.

There were ten studies[22, 28-34, 38, 39] (See Table 2) that met these criteria and hence evaluated prevalence (risk) of overweight as an outcome. Four studies[22, 34, 38, 39] reported no association. One of these studies[38] involved a small (n=71), highly selected sample. A second small (n=313) study by Burdette et al.[34] reported no association between introduction of solids at < 4 months (assessed retrospectively when the children were three years of age) and overweight (BMI > 85th percentile) at five years of age. Reilly et al.[39] also showed no association of solid introduction (<1, 1-2, 2-3, 3-4, 4-6 months assessed when the children were 6 months old)

with obesity (BMI ≥ 95th percentile) at seven years of age in the large (n=7758) ALSPAC cohort, born in 1991/1992. In another comparatively older cohort born 1988-94, Hediger et al.[22] estimated a statically significant but clinically non-significant 0.1% reduction in risk of overweight at 3-5 years for each month solids were delayed.

The six remaining studies[28-33] all showed a positive association between early introduction of solids (< 4 months of age) and obesity risk. Three represent large good quality cohort studies[28-30] but all use introduction of solids < 4 months as the exposure. Two of these high quality studies[28, 30] were based on analyses of the contemporary large (n>13,000) representative UK Millennium Cohort study. Using a robust definition of overweight status (IOTF cut offs for BMI[45]) both reported a significant but small positive association (OR 1.12) with early introduction of solids (<17.4 weeks [4 months] and < 3 months) at both three[28] and five[30] years of age. Both analyses were adjusted for a comprehensive range of covariates including breastfeeding duration. Huh et al.[29] report a strong effect of introduction of solids at < 4 months compared to 4-5 months on prevalence of obesity (≥ 95th percentile) at three years of age in formula fed infants (OR 6.3) but no effect in infants who received some breastfeeding beyond 4 months. The three remaining studies are of limited quality.[31-33] The small Chinese case-control study (n=81 pairs, age 3-6 years) reports an OR=11 (95%CI 2-22) for obesity (not overweight) of solid introduction <4 months. Gungor et al.[31] report a small (n=102) study of children retrospectively defined as 'at risk of overweight' based on rapid weight gain (≥8.5kg) from 0-2 years. In a simple univariate comparison the mean age of solid introduction (yes/no at 1,2,4, or 6 months clinic visits) in those who were at risk of overweight (>85th percentile) or not at 6-8 years of age was 5 versus 6.5 months. Seach et al.[32] is the only study in this category to evaluate later introduction of solids and report that introduction below the median age of five months relative to delay until 6 months was associated with a 30% increase in prevalence of overweight (IOTF cut offs for BMI[45]) at 10 years of age in children born 1990-4. However, this study is small (n=307) and limited by bias related to the selection criteria of atopic family history and loss to follow up of 50% of participants who had much shorter duration of breastfeeding (36 vs 48 weeks) and earlier solid introduction (19 versus 20 weeks). A further major limitation of this study is that there was no adjustment for maternal BMI.

Studies that enable evaluation of current guidelines by including a comparator group ≥ 6 months of age

Seven studies[21-23, 29, 33, 39, 44] compared outcomes of introduction from 3-5 versus ≥ 6 months of age. Five of these reported no significant association with obesity risk.[21, 23, 33, 39, 44] One of these, a very large good quality study[39], reported no association based on a six age categories ranging from < 1 to > 6 months. Another large, robust study[44] showed no effect of introduction at 0-3 vs 3-6 vs > 6 months on change in weight-for-height z-score. Two good quality studies[22, 29], reported a positive association with later indicators of obesity risk. Huh et al.[29] examined the impact at 3 years of age of solid introduction at < 4 or ≥6 months relative to the reference group of 4-5months in separate analyses of breastfed and formula fed infants. They reported no association for breastfed infants but a trend for increased risk (OR 3.6 95%CI 0.8-16.3, ns) of obesity prevalence (≥ 95th percentile) in formula fed infants with later solid introduction (≥ 6 months), although there were only 25 (9%) infants in this category. They also showed a six-fold increase in obesity prevalence at 3 years associated with early introduction (< 4 months) in formula fed but not breastfed infants. The second study[22] involved a large representative sample, compared solid introduction at < 4 months, 4-5 months and ≥ 6 months and reported a *'relatively minor'* (0.1%) reduction in risk of overweight (BMI > 85th percentile) at 3-5 years associated with each month delay in introduction of solids.[22] Notwithstanding the strengths of this study, it did not adjust for exclusive breastfeeding and the age of solid introduction was assessed retrospectively when the child was 3-5 years old.

Seach et al.[32] report a positive association between prevalence of overweight at 10 years of age and solid introduction in weeks treated as a continuous variable. The authors conclude that the adjusted OR of 0.9 per week translates to a 33% reduction in risk of overweight with delay of introduction from five (median introduction 20 weeks) to six months. There was no effect of any or duration of exclusive breastfeeding. The significant limitations of this study, including no adjustment for maternal BMI have been discussed above.

Evidence from randomised controlled trials

A single study[21] has examined the effect of timing of solid introduction on growth ≥ 12 months using a randomised trial design. The prospective trial by Mehta et al.[21] sponsored by a baby food company found no difference in weight, length or body composition (DXA) at 12 months of age in 147 infants randomised to receive commercial baby food or parents' choice

from either 3-4 or 6 months. Infants were exclusively formula fed from randomisation at 3 months of age. Breastfeeding prior to randomisation was not an exclusion criteria but prevalence in the allocated groups was not reported.

Studies that consider the interaction between age of solid introduction and breastfeeding or formula feeding.

In the small but very detailed DARLING study[23] 60 infants breastfed to 12 months (< 120 mls formula) were compared to 45 infants fully formula fed from < 3 months. At 18 months of age no association was found in either group between timing of solid introduction (16-25 weeks vs ≥ 26 weeks) and weight-length z scores or growth velocity. Seach et al.[32] and Haschke et al.[37] report no evidence of interaction between exclusive breastfeeding and the age of solid introduction. Both studies give very little detail of the interaction analysis, have small sample sizes and are potentially inadequately powered. Although Schack-Nelson et al.[26] is a larger study they simply state that there was no interaction but give no details.

Discussion

None of the 26 studies included in this review explicitly (or prospectively) evaluated obesity risk of the current WHO recommendations[1] to commence complementary feeding at 6 months or older, whereby the effect of early introduction of solids (prior to 6 months) is examined independently of exclusive breastfeeding to 6 months. Ten studies[22, 25-33] reported a positive association. Of these only two[28, 30] were large good quality studies and both examined the outcome of early (<4 months) solid introduction. None of the four good quality studies[22, 29, 39, 44] that directly evaluated current guidelines provided evidence of any clinically relevant protective effect of solid introduction from 4-5 versus ≥ 6 months of age.

Overall, the evidence suggests that very early introduction of solids at ≤ 4 months is associated with increased obesity prevalence or risk, particularly in infants born in the last decade and who are formula fed. Only one study[32] suggests that delaying solids introduction from 5 to 6 months is associated with a significant reduction in risk of overweight at 10 years of age. However this small study is subject both to selection and retention bias and uncontrolled confounding related to parent weight status. Overall, there is little evidence for a protective effect against adverse weight status outcomes associated with introducing solids at 4-6 months rather than at 6 months as recommended by the WHO.[1, 2] A very recent systematic review,[18] and a more general 2012 review[46] of selected studies reached a similar conclusion.

Methodological, ethical and practical challenges

This review highlights the heterogeneity and imprecision of measurements used. Firstly, interpretation and definitions of 'starting solids' and 'breastfeeding' are highly variable. Age of solid introduction could be interpreted as the age at which the spoon and/or solids are first offered, even if initially rejected, through to the age that solids are eaten daily and most studies were not explicit. Compounding these definitional issues is the fact that most studies assessed the age of introduction retrospectively, often several years later. Only Heideger et. al.[22] defined introduction explicitly (as eating daily) and this was assessed at 3-5 years of age. Although most studies provided some level of adjustment for breastfeeding, the definitions of breastfeeding are even more problematic. They include the very crude 'never' versus 'ever' or currently 'any yes versus no' or categorical or continuous definitions of duration in weeks or months. This is further complicated by the potential need to distinguish between

breastfeeding that is exclusive, fully or partially supplemented with varying intakes of formula or even solids. Only five studies attempted to adjust for exclusive breastfeeding[25, 32, 34, 37, 38] but duration was ≤ 4-5 months. Given the inextricable link in the current guidelines between duration of exclusive breastfeeding and timing of complementary feeding, this represents a major limitation of the current evidence. In addition to definitional problems, the assessment of the age of any early feeding milestone in months lacks precision. For example introducing solids at four months could include ages from 16-20 weeks and represents a 25% variation. These issues are compounded by recall bias associated with retrospective assessment of both breastfeeding and solid introduction exposure.

The issue of reverse causality is particularly important.[3, 47] Rapid weight gain and size at 6 months are important independent predictors of both future obesity status and CVD risk profile.[48-50] It is entirely plausible that babies that are bigger or grow more rapidly are perceived by their mothers to be, or indeed may actually be hungrier and demand solids earlier. Formula fed infants grow more rapidly and are also more likely to be introduced to solids earlier by mothers who themselves are likely to be younger, less educated and to smoke.[7, 47, 51] Few studies have adequately addressed interactions between these factors in analyses. The study by Huh et al.[29] is important as it showed a strong association between weight status at three years with early introduction of solids (< 4 months) in infants who were never breastfed or ceased breastfeeding before four months, independent of the rate of early (0-4 months) weight gain. The same association was not seen in the infants who continued any breastfeeding beyond four months, who as a group had slower early weight gain. Models were adjusted for BMI of both parents. Effectively this study controlled for the effect of mothers' responding to early weight gain by introducing solids early and any interaction between cessation of breastfeeding and early solid introduction.

A further limitation of the evidence base is the scarcity of good quality prospective studies that examine important behavioural outcomes of not just the timing but also the process of complementary feeding such as texture tolerance, development of food preferences and dietary variety. For example there is growing interest in the process of baby-led weaning that promotes introduction of complementary feeding at six months by allowing the infant to self-feed family foods rather than being spoon-fed purees. Although probably highly variable in implementation, baby-led weaning is postulated to enhance the infant capacity to self-regulate intake and acceptance of a wider variety of tastes and textures. However, there are

very few studies that have examined outcomes such as age of solid introduction, duration of breastfeeding, weight status, dietary variety and nutritional adequacy.[52] Increasingly, evidence points to the influence of the early feeding environment on the development of eating behaviours and dietary intake patterns that track into early childhood and beyond and are potentially associated with obesity risk.[53, 54] Studies that examine the associations of the 'what and how' in addition to the 'when' of complementary feeding with outcomes that extend beyond weight status to include those relevant to long term healthy eating patterns and chronic disease risk are needed.

The very small number of randomised trials and purpose-designed prospective studies point to the ethical dilemmas and practical design issues associated with answering the research questions addressed by this review. It is difficult to prospectively evaluate guidelines via an RCT design as this requires a comparator group that does not comply with the guidelines. Even if ethical approval to randomise infants already introduced to formula (and thus not exclusively breastfed) to introduction of solids at 4 versus 6 months was achieved, the heterogeneity of mothers and infants and the complex, interactive and bidirectional nature of the infant feeding dynamic would present design, sample size and analytical challenges. In addition, there are pragmatic issues related to mothers of young children as participants. Mothers juggle increasingly complex family and work commitments in the context of variable maternity leave and child care arrangements and supports. Acceptable consent and retention rates, selection bias towards better educated older participants and complete data collection are major challenges.[45] The large, intense, long term studies required to provide quality evidence to guide infant feeding recommendations present considerable ethical, feasibility and funding challenges.

Conclusion

The evidence regarding the association of early solid introduction with later obesity risk is effectively limited to cohort studies with extensive methodological limitations. A key issue is that very few studies effectively consider the interaction between exclusive breastfeeding and age of solid introduction. The majority of studies showed no association and these include the only RCT and five large quality studies with robust covariate adjustment. There is some evidence from two large good quality studies for increased obesity risk associated with very early introduction (< 4 months). A third good quality study confirms this association in formula fed but not breastfed infants. None of the four good quality studies that directly

evaluated current guidelines provide evidence of any clinically relevant protective effect of delaying solid introduction from 4-5 to ≥ 6 months of age. Overall the introduction of solids prior to 4 months may result in increased risk of childhood obesity but there is little evidence of adverse weight status outcomes associated with introducing solids at 4-6 rather than at 6 months.

The age of introduction of solids is an area of interest and controversy, at least in part due to the interaction with exclusive breastfeeding recommendations and the large and persistent gap between policy and practice. The political, policy and practice emphasis on exclusive breastfeeding has selectively narrowed the infant feeding research agenda. There is no doubt that in developed countries breastfeeding initiation and duration need improving, but this should not be at the expense of research and promotion of satisfactory timing and process of complementary feeding. Furthermore, albeit perhaps unintentionally, the wording of the current WHO guidelines (at 6 months [180 days] of age)[55] encourages age- rather than cue-related introduction of solids. As with other child development milestones, there is individual physiological and developmental variability that influences the 'right' time to commence complementary feeding for an individual infant. It is likely that mothers would value and benefit from evidence-based information around recognising and interpreting signs of developmental readiness for complementary feeding. There is a clear need for more and better evidence to inform guidelines on the when, what and how of complementary feeding. However, rigid interpretation of current guidelines and policies contributes to the significant ethical, methodological and feasibility challenges associated with building this evidence base.

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Table 1 Summary of studies published after 1990 examining association between age of introduction to solid foods and obesity risk beyond 12 months of age

Study	N	Born after 1990	Age follow up	Measurement of exposure : Age solids < 4 months (mths)	Categorical definition overweight/ obesity risk	Adjusted BF - Measurement	Adjusted Exclusive BF	Assessment age solids, BF	Adjustment [1] maternal education, BMI, smoking, SES	Interaction BF and age solids	Significant finding (based on adjusted analyses)
Mehta 1998[21]*	147	✓	12 mths	✓ 3-4 vs 6 mths	× weight g, length cms, % fat mass	NA RCT design	Exclusively formula fed from randomisation at 3 mths	Concurrent – 3-monthly contact	✓ maternal education, BMI – no group difference SES, smoking not considered	×	No
Sloan 2008[27]	210	✓	14 mths	✓ < 4 vs ≥ 4 mths	×(z scores)	Continuous -weeks	×	Retrospective 10-18 mths	✓ × BMI	×	Yes Solids < 4 vs ≥ 4 mths 14 mth wt z score 0.4 vs -0.1 Wt gain z score 2-14 mths -0.2 vs 0.3
Heinig 1993[23]	105	×	18 mths	× BF infants - 16-25w vs >26wks FF infants – wks	×(z scores)	NA Either BF (no formula) or FF (from 3 mths) to ≥ 12 mths	×	Concurrent – monthly contact	NA FF matched to BF for demographics × BMI	BF FF analysed separately	No
Morgan 2004[19]	680	✓	18 mths	✓ ≤ 12 wks vs > 12 wks	× Weight kg, length cm	Predominantly BF vs formula in is 6 weeks	"predominantly BF for at least 6wks"	Concurrent - 6,12 26 wks	✓ ×BMI	×	No Considered size at 12 wks
Forsyth 1993[20]	392	×	24 mths	✓ < 8 vs 8-12 vs > 12 wks	× (z scores)	Categorical EBF or full or mixed ≥13 wks	×	Concurrent-monthly contact	✓ ×BMI but maternal height	×	No
Grote 2011[43]	687	✓	24 mths	✓ 4 categories: ≤13wks ; 14-17wks;18-21wks; ≥22wks	×(z scores)	NA All fully formula-fed from 8 weeks	NA	Concurrent Monthly 3d records	✓	NA	No
Durmus 2012[41]	584	✓	2 yrs	✓ 3 categories:<4mths; 4-5mths; >5mths Introduction fruit, vegetables only	× Σ skin fold thicknesses 2-4 sites	Categorical BF: never; <4mths; ≥ 4mths	×	Retrospective - Questionnaire at 6mths	✓ Comprehensive adjustment	×	No
Haschke 2000[37]	319/ 185	✓	2 and 3 yrs	✓ < 4 vs > 4-5 mths BF infants only	× (z-scores)	Continuous - months	EBF to 4-5 months comparator group	Concurrent – monthly contact	Education only mid parental height	✓ Not significant 1-24 or 1-36 months	No
Hawkins 2009[28]	13,188	✓	3 yrs	✓ < 17.4 vs ≥ 17.4 wks	✓ IOTF overweight	Categorical never vs <17.4 vs ≥ 17.4 wks	×	Retrospective – 9 mths age	✓ Comprehensive adjustment	×	Yes OR 1.12

Study	N	Born after 1990	Age follow up	Measurement of exposure : Age solids < 4 months (mths)	Categorical definition overweight/ obesity risk	Adjusted BF - Measurement	Adjusted Exclusive BF	Assessment age solids, BF	Adjustment [1] maternal education, BMI, smoking, SES	Interaction BF and age solids	Significant finding (based on adjusted analyses)
Griffiths 2009[36]	10,533	✓	3 yrs	✓ < 17.4 vs ≥ 17.4 wks	× conditional wt gain z score	Categorical Ever BF – Y/N <4 vs ≥4mths	×	Retrospective – 9 mths age	✓	×	No
Hediger[a] [22]	2865	1988-94	3-5 yrs	<4, 4-6, >6 mths (first fed solids daily)	✓ Percentile 85th-94th; ≥ 95th	Categories never full BF ≤2, 3-5, 6-8, ≥9 mths	×	Retrospective 3-5 yrs age	✓	×	Yes Adj OR 0.9994 each month delayed – clinically ns
Huh 2011[a] [29]	847	✓	3 yrs	✓ < 4 vs 4-5 vs ≥6mths	✓ ≥ 95th %ile (obesity)	NA BF any ≥ 4mths FF never/stopped BF <4mths	×	Concurrent– 6 mths age	✓ No smoking Change in wt-age z score 0-4 mths Wt –age z score 0-4 mths	BF FF analysed separately	No BF infants Yes FF infants <4 mths OR 6.3; ≥6 mths OR 3.6 relative to 4-5mths 9% (n=25) FF infants solids ≥6 mths
Van Rossem 2012[44]	3184	✓	45mths	✓ 0-3mths; 3-6mths; >6mths	× ΔWFH z- score	Yes/No at 2mths	×	Retrospective 12 months, categorical response options	✓	×	No
Kuperberg 2006 [38]	71	✓	4 yrs	✓ < 4 vs ≥ 4 mths	✓ BMI ≥ 85th %ile	EBF > 3mths Partial < 3mths EBF Excl FF 0-3 mths	✓	Concurrent home visits 3 and 48 mths age	Unclear ✓BMI	×	No
Zive 1992[24]	331	×	4 yrs	Continuous mths	× Σ skin fold thicknesses 2 sites	Continuous mths	×	Retrospective 4 yrs age	✓	×	No
Robinson 2009[40]	569	✓	4 yrs	✓ 4 categories Up to 3,4,5, >5 mths	× Fat, lean mass (kg)	6 categories any BF 0, <1, 1-3, 4-6, 7-11, ≥12 mths	×	Concurrent – 6 and 12 mths age	No SES	×	No
Burdette 2006[34]	313	✓	5 yrs	✓ Solids<4 and sweetened beverages < 6 months vs other	✓ BMI ≥ 85th %ile Fat, lean mass (kg); % fat	4 different approaches to categorisation- never/ever; duration, mix BF and solids	✓ EBF to 4mths	Retrospective 3 yrs age	✓	×	No
Griffiths 2010[35]	11,653	✓	5 yrs	✓ < 17.4 vs ≥ 17.4 wks	× Conditional wt gain	Categorical < 17.4 vs ≥ 17.4 wks	×	Retrospective – 9 mths age	✓	×	No
Brophy 2009[30]	13,745	✓	5 yrs	✓ < 3 vs ≥ 3mths	✓ IOTF obesity	Not included	×	Retrospective – 9 mths age	✓	×	Yes Adj OR 1.2 (1.02-1.5)

Study	N	Born after 1990	Age follow up	Measurement of exposure : Age solids < 4 months (mths)	Categorical definition overweight/ obesity risk	Adjusted BF - Measurement	Adjusted Exclusive BF	Assessment age solids, BF	Adjustment [1] maternal education, BMI, smoking, SES	Interaction BF and age solids	Significant finding (based on adjusted analyses)
Zhou 2011[33]	162	✓	3-6 yrs	<4 vs 4-6 mths >6 vs 4-6 mths (case control)	✓ IOTF obesity	No – p>0.1 univariate analysis	×	Retrospective 3-6 yrs, verified health record	No BW	×	Yes <4mths OR 10.1(2.4-33) No >6 mths OR 3.9(0.6-26) p=0.29
Reilly 2005[39]	7758	✓	7 yrs	✓ 6 categories <1, 1-2, 2-3,3-4, 4-6, > 6mths	✓BMI ≥ 95th %ile	Never, EBF vs stopped or non-EBF at 2 months	×?	Concurrent – 6 mths	No BMI rapid early growth, wt z score 8, 18 mths; wt gain 0-12 mths	×	No
Wilson 1998[25]	412	×	7 yrs	✓ <15 vs ≥ 15 wks Continuous	× % fat	EBF ≥ 15wks, partial BF before 15 wks; formula only – yes/no	✓	Concurrent-monthly contact	×education or BMI Maternal ht Wt first solid feed	×	Yes <15 vs ≥ 15 wks Wt z score 0.02 vs-0.09 % Fat 18.5 % vs 16.5% No effect BMI
Gungor, 2010[a] [31]	102	✓	6-8yrs	× continuous months	✓BMI ≥ 85th %ile	Duration any mths BF with no formula > 6 mths	×	Retrospective review records well baby visits 1,2,4,6,9 mths	×	×	No Children with rapid early weight gain who were **not** ow at 6-8 years of age had later solid introduction
Seach 2010[a] [32]	307	✓	10yrs	× continuous wks	✓ IOTF overweight	Duration EBF and any BF wks	✓	Concurrent, monthly phone calls	✓ ×BMI; BW, child care	✓ ns	Yes OR 0.9(0.85-0.96)/week
Garden 2012[42]	616	✓	11.5y	✓ Yes/no at 3 months ≤ 3 mthsvs >3 mths	BMI trajectories 0-11.5yrs	Duration Any - 0-3; ≥3-<6; ≥6 mths	×	Concurrent Interviews at 3, 6 mths	✓ Parent BMI at age 8 years	×	No
Schack-Neilson 2010[26]	1546	×	42yrs	× continuous mths Introduction - spoon feeding; firm food	BMI >25; ≥ 30kg/m^2 Self-reported height and weight	Duration any mths	×	Retrospective – 12 mths	✓	✓ ns	Yes 'firm food' but not 'spoon feeding' at 42 yrs; neither at 13 previous ages OR 0.92

Adapted in part from Moorcroft 2010; [a] not included in Moorcroft 2010; N number participants; %ile – percentile; IOTF International Obesity Task Force cut offs (ref); NA not applicable given design or analytical approach; ns not significant; adjOR adjusted odds ratios; yrs years, mths months, wks weeks

[1] well established maternal determinants of both breastfeeding and age solid introduction [4, 56]; variables were evaluated for inclusion in models but may not have been included; BMI – could be self report, pre pregnancy; SES - Socioeconomic status may include income or other relevant measures e.g. social class; Smoking may refer to smoking during pregnancy and/or smoking near child (i.e. current smoker) and/or number of people smoking in household. * included as RCT