



Digital Health Interventions for Parental Engagement in Early Childhood Nutrition and Feeding: A Review

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Abstract

This review synthesizes global empirical evidence regarding digital health interventions designed to optimize parental engagement within early childhood nutrition and feeding frameworks. By systematically analyzing diverse modalities such as mobile applications, specialized websites, text messaging platforms, and interactive social media, the synthesis characterizes parental involvement patterns across multi dimensional behavioral trajectories and exposure frequencies. The extracted findings indicate that although advanced digital architectures successfully deliver tailored educational resources and evidence based behavior change mechanisms, sustaining active caregiver usage beyond initial uptake remains a critical challenge. Significant improvements in child dietary outcomes and parental responsive feeding practices are heavily concentrated within high active usage thresholds, whereas passive platform exposure yields minimal or transient behavioral shifts. Furthermore, intervention efficacy is strongly moderated by structural socio demographic variables, revealing profound equity divides where resource constrained families face heightened attrition driven by digital literacy limitations. Consequently, advancing pediatric nutritional health systematically necessitates a paradigm shift toward inclusive user centered architectures integrated within routine healthcare services to stabilize long term caregiver engagement across diverse populations.

Keywords : Parental Engagement, Digital Health, Child Feeding, Nutrition Behavior, Health Equity.



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INTRODUCTION

The global landscape of maternal and child health has witnessed a rapid diffusion of digital platforms into the domain of early childhood nutrition, a trajectory propelled by the near universal penetration of mobile connectivity and the growing willingness of health systems to embed behaviour change support within scalable, low cost delivery channels. Web based and application based programs are increasingly positioned as instruments capable of reaching parents across geographically dispersed and resource constrained settings while offering tailored, interactive content that conventional face to face counselling struggles to replicate at comparable scale (Zarnowiecki et al., 2020). This expansion is not incidental. It coincides with mounting recognition that feeding practices established during infancy and toddlerhood exert lasting influence over dietary trajectories, weight status, and chronic disease susceptibility later in life, which situates the first years of life as a uniquely consequential window for intervention. Systematic evaluations of nutrition promotion websites and applications indicate that when appropriately designed, such tools can enhance parental knowledge and self efficacy, yet the same evidence base cautions that usability shortcomings and inconsistent implementation frequently attenuate these gains before they translate into measurable behavioural change (Zarnowiecki et al., 2020, Wibowo et al., 2024). Complementing this picture, mobile health initiatives directed at families from lower income backgrounds have demonstrated that digital delivery can be feasible and acceptable even among populations traditionally underserved by conventional programming, reinforcing the argument that digital modalities carry genuine equity potential when engagement is properly cultivated (Power et al., 2024). Taken together, this body of work signals a field that has matured technologically while still grappling with the more fundamental question of how sustained parental involvement with these tools can be reliably generated and maintained.

A closer reading of the empirical record reveals findings that are individually persuasive yet collectively difficult to reconcile into a coherent account of what drives effective parental engagement. The Food4toddlers trial, a parent focused eHealth intervention targeting fruit, vegetable, and discretionary food intake among toddlers, produced measurable dietary improvements and demonstrated that structured digital content delivered over an extended period could shift specific feeding behaviours in a randomized controlled design (Røed et al., 2021). The accompanying process evaluation of the same intervention, however, exposed considerable heterogeneity in how parents actually interacted with the platform, showing that exposure to intended content was uneven and that engagement declined progressively as the intervention period advanced, a pattern that complicates any straightforward attribution of the observed dietary effects to consistent program use (Røed et al., 2020). A parallel systematic review of parent based eHealth interventions targeting physical activity, dietary behaviours, and sleep in preschoolers similarly concluded that while pooled effects trended favourably, the underlying studies varied so substantially in intervention intensity, delivery format, and engagement measurement that confidence in any unified mechanism of action remained limited (Zhou et al., 2023). Evidence from a primary care based eHealth obesity treatment pilot developed for vulnerable paediatric patients further complicates the synthesis, as feasibility outcomes were encouraging even though retention and active platform use among participating families proved difficult to sustain across the intervention timeline (Yudkin et al., 2023). Read critically rather than descriptively, these studies converge on a paradox in which digital interventions repeatedly demonstrate short term promise while struggling to establish the durable behavioural engagement that theoretical models of digital health assume as a precondition for lasting effect.

This paradox exposes a series of conceptual and methodological gaps that the existing literature has not adequately resolved. Predictors of engagement in parental mHealth interventions, including demographic characteristics and contextual constraints, have been shown to shape participation trajectories in ways that current intervention designs rarely anticipate or adapt to, suggesting that engagement is treated too often as a uniform outcome rather than a differentiated process shaped by who the parent is and what circumstances surround them (Sandborg et al., 2024). Systematic reviews of mobile learning applications aimed at changing maternal feeding behaviour report similarly fragmented evidence, noting that outcome measures, exposure metrics, and follow up durations differ so widely across studies that cross study comparison borders on methodologically unsound (Wibowo et al., 2024). Compounding this, evaluations of nutrition promotion digital tools have repeatedly flagged the absence of standardized engagement metrics capable of distinguishing superficial exposure from meaningful behavioural interaction, leaving reviewers unable to determine whether a documented improvement in feeding outcomes reflects genuine sustained use or a brief period of novelty driven contact with the platform (Zarnowiecki et al., 2020). Even within trials explicitly designed for low income and vulnerable populations, engagement has tended to be reported as a secondary or exploratory outcome rather than a primary theoretical construct, which limits the field's capacity to build predictive models linking specific design features to specific engagement behaviours (Power et al., 2024). The literature, in short, possesses no shared operational definition of parental engagement, no consistent framework for measuring its frequency or depth, and no agreed account of how engagement translates mechanistically into changed feeding practice.

The scientific and practical stakes of resolving this gap are considerable. Childhood obesity and suboptimal feeding practices remain leading contributors to the global non communicable disease burden, and digital interventions are increasingly proposed as the most cost effective route to population level prevention precisely because their marginal cost of reach is low compared with clinic based counselling (Zhou et al., 2023). Yet if engagement continues to be inconsistently defined and weakly linked to outcome measurement, health systems risk investing in digital infrastructure whose real world effectiveness cannot be reliably predicted or replicated once removed from the controlled conditions of a trial. Predictors of participation identified in large scale mHealth trials suggest that certain parent subgroups are structurally less likely to sustain engagement, raising the practical concern that digital nutrition programs, rather than closing disparities in child feeding outcomes, may inadvertently reproduce or widen them if design decisions are not informed by a clearer understanding of who disengages and why (Sandborg et al., 2024). The pilot evidence from primary care settings further underscores that feasibility alone cannot substitute for a robust theory of engagement, since programs that are acceptable in principle may still fail in practice if the mechanisms sustaining parental attention

and interaction are not explicitly designed for and measured (Yudkin et al., 2023). Addressing this unresolved question is therefore not merely of academic interest but a precondition for translating digital nutrition interventions into interventions that perform reliably when scaled beyond the research setting.

Positioned against this backdrop, the present review occupies a deliberately synthetic space between intervention effectiveness research and the more specific literature on engagement measurement and behaviour change mechanisms. Rather than repeating prior reviews that catalogue intervention outcomes in aggregate, this review foregrounds parental engagement itself as the primary analytic construct, treating frequency, depth, and interaction as dimensions worthy of independent classification rather than incidental process indicators (Zarnowiecki et al., 2020). It draws on the demonstrated dietary effects of structured eHealth programs such as Food4toddlers while simultaneously interrogating the process level evidence that complicates a simple efficacy narrative, thereby situating outcome data and engagement data within a single interpretive frame rather than treating them as separate strands of inquiry (Røed et al., 2021, Røed et al., 2020). It also extends the equity considerations raised by trials conducted among lower income families into a broader synthesis of moderators that shape engagement trajectories, aligning with calls in the mHealth literature for greater attention to demographic and contextual predictors of sustained participation (Power et al., 2024, Sandborg et al., 2024). By deliberately bridging these previously fragmented strands, the review is positioned to generate a more integrated account of how, for whom, and under what conditions digital health interventions succeed in engaging parents around early childhood nutrition and feeding.

The objective of this review is to synthesise the available evidence on parental engagement with digital health interventions for early childhood nutrition and feeding using a structured classification framework that examines behavioural frequency, depth, and interaction alongside the design components intended to elicit them. It aims to deconstruct intervention components in order to align specific engagement strategies with their theorised behaviour change mechanisms, to benchmark the diverse measurement approaches currently used to capture engagement and exposure, and to identify patterns connecting the intensity of engagement with observed feeding related outcomes. Beyond outcome synthesis, the review seeks to consolidate the moderating role of design and contextual factors that shape differential engagement and equity related change across parent populations. Theoretically, the review contributes a unifying lens through which engagement can be understood as a multidimensional construct rather than a binary indicator of program uptake. Methodologically, it contributes a classification framework that can guide more consistent measurement and reporting of engagement in future digital nutrition intervention research, thereby supporting the design of scalable, parent centred interventions capable of sustaining meaningful engagement across diverse implementation contexts.

RESEARCH METHODS

This review is non-empirical in nature, constituting a structured narrative synthesis rather than a primary experimental or simulation based investigation, and it is therefore organised around an explicit conceptual framework that guided the classification and interpretation of the included evidence rather than around a data collection protocol. The framework was constructed to treat parental engagement not as a single undifferentiated outcome but as a multidimensional construct that could be systematically decomposed into frequency of interaction, depth of interaction, and the specific behavioural interaction patterns exhibited by parents across different digital modalities including mobile applications, websites, text messaging, and social media platforms. Each intervention identified for inclusion was mapped against this framework by first classifying its behaviour change functions, such as tailoring, reminders, goal setting, and social support prompts, and then aligning those functions with their theorised mechanism of action within the broader logic of intervention mapping. This conceptual scaffolding was extended to incorporate a second analytic dimension concerned with engagement measurement practice itself, distinguishing self report logs from objective platform derived metrics so that the heterogeneity in how engagement had been operationalised across studies could be made explicit rather than obscured within a pooled effect estimate. The originality of this framework lies in its refusal to conflate exposure with engagement, instead requiring that each intervention be characterised along both an intensity axis and a mechanism axis before its reported outcomes were considered interpretable, which distinguishes the present synthesis from prior reviews that report effectiveness without first establishing what engagement meant operationally in each source study.

The analytical and synthesis procedures underpinning this classification framework were designed to maximise methodological robustness given the acknowledged heterogeneity of the source literature. Records published between 2020 and 2025 were systematically screened from electronic databases to identify quantitative or mixed methods digital interventions targeting parents of young children, with screening conducted against predefined eligibility criteria concerning population, intervention modality, and outcome relevance to feeding or nutrition behaviour. Data extraction proceeded study by study to capture intervention characteristics, engagement metrics, and outcome direction, after which each record was coded against the classification framework described above rather than being synthesised through simple vote counting or narrative description alone. Because the included studies varied substantially in design, duration, and measurement approach, a structured thematic synthesis was applied in place of meta-analytic pooling, allowing patterns in engagement and effectiveness to be identified across studies while preserving the contextual nuance that a purely quantitative aggregation would have obscured. Analytical rigour was reinforced through cross checking of extracted classifications against the original source descriptions to reduce misclassification of engagement metrics, and through explicit attention to moderating design and contextual factors that shaped differential engagement and equity related outcomes across parent populations. This combination of structured classification, thematic synthesis, and deliberate moderator analysis constitutes the methodological uniqueness of the review, positioning it to generate transferable insight into how engagement should be conceptualised and measured in future digital nutrition intervention research rather than merely summarising whether existing interventions were effective.

RESULTS AND DISCUSSION

Modality Diversity and the Behavioural Architecture of Digital Interventions for Parental Engagement

The digital interventions examined across this literature display considerable technological heterogeneity, spanning mobile applications, parent focused websites, text messaging platforms, social media channels, and sensor supported tools (Zarnowiecki et al., 2020). This diversity extends beyond surface level interface differences and reflects divergent assumptions about how parental attention can be captured and sustained within early childhood feeding contexts. Acceptability research conducted among vulnerable family populations indicates that modality choice itself carries consequences for reach, since platforms differ markedly in the barriers they impose on continued use (Eppes et al., 2022). Mapping this modality landscape against embedded behaviour change functions constitutes a necessary step before questions of measurement or effectiveness can be meaningfully addressed.

Among the mobile application based interventions identified, considerable variation emerges in the design logic underlying user interaction. Fammeal exemplifies a gamified approach in which reward structures and interactive tasks sustain parental participation while embedding tailored educational content and social support prompts (Afonso et al., 2020). A markedly different philosophy is evident in BabyByte, where qualitative formative research preceded development so the resulting application would reflect responsive feeding practices parents themselves identified as relevant (Mobley et al., 2023). These contrasting pathways, one driven by behavioural reinforcement and the other by participatory design, indicate that mobile applications cannot be treated as a single homogeneous modality category.

A further mobile health application, AIM2Be, extends this modality by incorporating an analytic layer that classifies users into latent digital phenotypes based on their interaction patterns. This approach reframes engagement measurement as a classification problem rather than a simple frequency count, distinguishing parent subgroups by how consistently they interact with the platform (González et al., 2022). Such profiling suggests that modality alone does not determine engagement outcomes, since the same application can generate markedly different usage trajectories across different parent subgroups. This finding complicates any assumption that a single behaviour change mechanism operates uniformly once a digital tool has been deployed.

Parent focused eHealth websites constitute a second major modality category, distinguished from mobile applications through reliance on structured, sequential content delivery rather than gamified mechanics. The Food4toddlers program illustrates this format, delivering dietary guidance across an extended period with the explicit aim of shifting fruit, vegetable, and discretionary food intake among toddlers (Røed et al., 2021). A comparable logic underlies the Healthy Online Parental

Education program, which combines structured web based modules with targeted messaging to promote vegetable intake and active play among toddlers from lower income households (Lee and Oldewage Theron, 2022). Both examples position the website as a repository of curated guidance rather than a site of continuous exchange, carrying distinct implications for how sustained engagement must be conceptualised.

Theoretical grounding becomes more explicit in a subsequent generation of website based interventions that deliberately embed behaviour change theory into structural design rather than relying on content curation alone. A pilot randomised controlled study targeting obesity prevention among young children from lower income families constructed a multicomponent eHealth program organised around theoretical determinants of feeding behaviour (Lee et al., 2023). SmartFeeding4Kids adopts a related but self guided architecture, allowing parents to progress through structured modules promoting positive feeding practices without requiring synchronous clinician contact (Isabel et al., 2021). Table 1 consolidates this modality typology together with the behaviour change functions embedded within each format, illustrating how the website modality has evolved into a more deliberately engineered vehicle for behaviour change.

Table 1. Typology of Digital Intervention Modalities and Associated Behaviour Change Functions Identified in the Reviewed Literature

Modality Category	Representative Intervention or Study	Core Behaviour Change Function	Source
Gamified Mobile Application	Fammeal	Gamification combined with tailored educational content and social support prompts to encourage healthy feeding behaviours	Afonso et al. (2020)
Qualitatively Informed Mobile Application	BabyByte	Formative participatory design used to develop responsive feeding education based on parental needs and user experience	Mobley et al. (2023)
Data Driven mHealth Platform	AIM2Be	Individual profiling of user engagement through digital phenotyping to personalize behavioural intervention	González et al. (2022)
Parent Focused eHealth Website	Food4toddlers	Structured educational content accompanied by dietary goal setting and progress monitoring	Røed et al. (2021)
Theory Anchored Website Program	Healthy Online Parental Education Program	Theory based educational modules promoting vegetable consumption, healthy eating patterns, and active play among children	Lee and Oldewage Theron (2022); Lee et al. (2023)
Self Guided Online Program	SmartFeeding4Kids	Self paced online learning modules designed to strengthen positive parenting and	Isabel et al. (2021)

		responsive feeding practices	
Text Messaging Program	Healthy Beginnings for HNEKids, Hunter New England Pilot mHealth Program	Dose calibrated reminders and scheduled behavioural prompts supporting sustained parental engagement	Brown et al. (2024); Jackson et al. (2025)
Social Media Based Program	PICNIc Peer Education Program, Facebook Based Nutrition Content	Peer education, social support, interactive communication, and engagement analytics to reinforce healthy nutrition practices	Henström et al. (2022); Henström et al. (2025); Hammersley et al. (2020)
Sensor and Speech Supported Tool	MAMAS; Change4Life Food Scanner	Automated dietary monitoring, sensor assisted tracking, and real time behavioural feedback to support healthy food choices	Jo et al. (2020); Mahdi et al. (2025)
Multicomponent Health Information Platform	WEE Baby Care; Samen Happie Program	Integrated communication between healthcare professionals and parents to support responsive parenting and nutrition management	Kling et al. (2020); Karssen et al. (2022)

Source: Developed by the authors from the reviewed literature.

As presented in Table 1, the typology extends beyond application and website formats to include text messaging programs that rely primarily on timing and dosage rather than interface richness. The Healthy Beginnings for HNEKids trial manipulated message dose directly, allowing the relationship between contact frequency and sustained parental involvement to be examined within a randomised design (Brown et al., 2024). A comparable pilot program implemented within the Hunter New England region delivered personalised, adaptive text messages to parents across the first 2000 days of a child's life (Jackson et al., 2025). Positioned against the richer interactive formats summarised in Table 1, text messaging represents a comparatively minimal but highly controllable modality whose function rests largely on repetition and timing.

Social media based programs constitute a further distinct modality category, characterised by reliance on existing platform infrastructures rather than purpose built applications or websites. The PICNIc peer education program used web and social media analytics to track reach and engagement across a nutrition promotion campaign directed at parents (Henström et al., 2022). A subsequent retrospective content analysis of parent directed nutrition material distributed through Facebook found that engagement varied according to content format and framing rather than platform reach alone (Henström et al., 2025). Earlier evidence from a randomised trial of an online healthy lifestyle program had already indicated that social media engagement could meaningfully shape outcomes for preschool aged children (Hammersley et al., 2020).

A smaller but technologically distinctive cluster of interventions moves beyond passive content delivery toward automated behavioural sensing embedded directly within the parent child interaction. The MAMAS system exemplifies this cluster by combining automated tracking with speech recognition technology to monitor mealtime interactions between parents and children in real time (Jo et al., 2020). The Change4Life Food Scanner application applies a related logic at a simpler technical level, enabling parents to scan food products and receive immediate feedback (Mahdi et al., 2025). These automated and scanning based tools shift the locus of behaviour change away from didactic content and toward feedback loops generated directly from parental action.

A final modality category comprises multicomponent platforms explicitly designed to coordinate communication among parents, clinicians, and community nutritionists rather than operating as a standalone consumer facing tool. The WEE Baby Care trial employed advanced health information technology to link parents with clinical and community nutrition support across a structured intervention period (Kling et al., 2020). The Samen Happie program adopted a comparable coordination logic within an application based parenting format, evaluating both process outcomes and effects on infant weight status through a randomised design (Karssen et al., 2022). Interventions of this kind suggest that engagement should sometimes be understood not merely as a relationship between a parent and an application but as a triadic exchange involving parents, professionals, and the connecting platform.

Read collectively, these modality categories show that behaviour change functions such as tailoring, reminders, goal setting, and social support are recombined differently across applications, websites, messaging systems, and social platforms. Acceptability research examining which intervention components parents actually value indicates that self monitoring and reflective tools are received positively yet tend to produce comparatively modest behavioural shifts relative to their design ambition (Christensen et al., 2022). Complementary feasibility evidence from a habit based online intervention suggests that framing behaviour change around automatic routines rather than deliberate decision making can improve both engagement and reported feeding behaviour (Engels et al., 2022). No unified taxonomy currently links specific behaviour change functions to specific modalities in a way that would allow designers to predict, prior to deployment, which combination best sustains parental engagement.

Measurement Heterogeneity and the Operationalisation of Parental Engagement Across Digital Interventions

Measurement heterogeneity emerges as a defining methodological challenge across the reviewed corpus, since engagement has been captured through self report logs in some studies and objective platform derived metrics in others (Zarnowiecki et al., 2020). This coexistence of measurement traditions complicates comparison across studies, because a login count and a self rated satisfaction score do not represent the same underlying construct. Acceptability research conducted among vulnerable family populations illustrates this problem further, reporting engagement through a mixture of usage frequency and perceived acceptability without a shared reporting standard (Eppes et al., 2022). Establishing what engagement actually means operationally within each source study becomes a necessary precondition for interpreting any subsequent claim about effectiveness.

A more conceptually grounded response to this heterogeneity treats engagement as a multidimensional construct rather than a single behavioural count. Predictors of participant engagement identified within the Let's Grow parental mHealth trial distinguish access, interaction, and loyalty as separate dimensions, each carrying distinct implications for how sustained involvement should be interpreted (Sandborg et al., 2024). This multidimensional framing directly challenges measurement practices that collapse engagement into total time spent or a single frequency count, since such practices obscure whether parents are merely accessing content or meaningfully interacting with it. Adopting a multidimensional lens requires studies to report several coordinated indicators rather than a solitary summary statistic.

Objective platform derived metrics represent one dominant measurement tradition within the reviewed literature, relying on data generated automatically through the digital tool itself rather than parental self report. A randomised controlled trial evaluating mobile technology for family based obesity prevention among lower income families operationalised engagement through video views and exposure frequency, treating these indicators as proxies for sustained parental attention (Power et al., 2024). Such metrics offer the advantage of objectivity and continuous capture, since they do not depend on parental recall or motivation to complete a survey instrument. They nonetheless capture exposure rather than meaningful interaction, leaving open the question of whether a recorded view corresponds to genuine engagement with intervention content.

Process evaluation methodologies constitute a related but analytically distinct measurement tradition, examining exposure and delivery fidelity as outcomes in their own right rather than as secondary indicators. The process evaluation accompanying the Food4toddlers trial assessed reach, dose, and fidelity separately from dietary outcomes, allowing engagement to be characterised

independently of whether the intervention ultimately changed children's food intake (Røed et al., 2020). This separation is analytically important, since an intervention with strong content and weak delivery may fail for reasons unrelated to the underlying behaviour change theory. Process evaluation in this form offers a more granular account of engagement than outcome linked metrics alone can provide.

A further measurement tradition draws on digital learning analytics, treating module completion and user satisfaction as indicators of sustained engagement with educational content. A quasi experimental evaluation of a mobile learning application directed at maternal nutrition behaviour recorded learning analytics and satisfaction scores alongside knowledge outcomes, positioning engagement as a precursor to demonstrated behaviour change (Wibowo et al., 2024). This approach aligns engagement measurement closely with educational theory, in which completion and satisfaction are treated as necessary though not sufficient conditions for knowledge transfer. Table 2 consolidates these divergent measurement traditions alongside their specific metrics, illustrating the absence of a single dominant approach across the reviewed literature.

Table 2. Engagement Measurement Approaches and Associated Metrics Reported Across the Reviewed Digital Nutrition Interventions

Measurement Approach		Specific Metric(s)	Representative Study	Source
Objective Analytics	Platform	Video views and exposure frequency	Mobile technology family based prevention trial	Power et al. (2024)
Process Evaluation	Exposure	Reach, intervention dose, and delivery fidelity	Food4toddlers process evaluation	Røed et al. (2020)
Digital Analytics	Learning	Module completion rate and participant satisfaction	Mobile learning application for maternal nutrition behaviour	Wibowo et al. (2024)
Composite Multidimensional Index		Access, interaction, and user loyalty	Predictors of engagement in a parental mHealth trial	Sandborg et al. (2024)
Pooled Meta Analytic Metrics		Adherence and platform usage indicators	Meta analysis of web based parental feeding interventions	Gomes et al. (2021)
Strategy Coding	Effectiveness	Tailoring, reminders, and incentive features associated with engagement	Systematic review of engagement improvement strategies	Grady et al. (2023)
Qualitative Barrier and Facilitator Mapping		Perceived usability, relevance, and clinical credibility	Mixed methods study of a childhood obesity application	Milne Ives et al. (2024)
Intervention Completion Rate		Proportion of intervention content completed	Parent based eHealth review of physical activity, dietary behaviour, and sleep	Zhou et al. (2023)
Website and Application Audit Metrics		Content quality and functional interactivity scores	Systematic evaluation of digital nutrition promotion websites and applications	Zarnowiecki et al. (2020)
Acceptability and Usage Frequency Scale		Perceived acceptability and platform usage frequency	Systematic review of digital media platforms among vulnerable families	Eppes et al. (2022)

Source: Compiled by the authors from the cited literature.

As Table 2 indicates, this measurement heterogeneity carries direct consequences for attempts to synthesise engagement outcome relationships across studies through meta analytic pooling. A systematic review and meta analysis of web based interventions targeting parental feeding practices reported that inconsistent operationalisation of engagement across included trials limited the precision of pooled effect estimates (Gomes et al., 2021). When one trial defines engagement through login frequency and another through completed modules, combining their reported effects risks aggregating conceptually distinct constructs under a single statistical label. This limitation is rarely acknowledged explicitly within primary studies, even though it shapes how confidently reviewers can draw conclusions about engagement and its relationship to feeding outcomes.

Recognition of this measurement problem has prompted a parallel body of research focused specifically on strategies capable of improving user engagement rather than merely recording it. A systematic review and meta analysis of engagement improvement strategies across nutrition, physical activity, and obesity focused digital interventions found that tailoring and reminder based approaches were associated with more favourable engagement outcomes than static content delivery (Grady et al., 2023). This evidence reframes measurement not as a passive recording exercise but as a diagnostic tool capable of identifying which design features are worth retaining or discarding. The strategies identified nonetheless remain evaluated against inconsistent outcome definitions, limiting the extent to which findings can be generalised across intervention types.

Qualitative and mixed methods research contributes a complementary measurement perspective by identifying which barriers and facilitators parents themselves regard as consequential for sustained engagement. A mixed methods study examining a childhood obesity application found that parents' perceived impact of the tool was shaped by usability, relevance to daily routines, and perceived clinical credibility rather than by objective usage volume alone (Milne Ives et al., 2024). These findings suggest that quantitative engagement metrics may miss dimensions of experience that meaningfully influence whether parents continue using a digital tool over time. Integrating qualitative barrier and facilitator evidence alongside quantitative metrics offers a more complete account of engagement than either measurement tradition can provide in isolation.

A persistent debate within this measurement literature concerns whether higher engagement dose consistently predicts more favourable feeding related outcomes. A systematic review of parent based electronic health interventions targeting physical activity, dietary behaviour, and sleep among preschoolers used intervention completion rates as its primary engagement metric, reporting improved feeding responsiveness among children whose parents completed a greater proportion of intervention content (Zhou et al., 2023). This association between dose and outcome is not uniformly replicated across the wider literature, since several trials report diminishing or inconsistent returns once a threshold level of exposure has been reached. Completion rate measurement, while intuitive, cannot alone determine whether the relationship between dose and outcome is linear, contingent on a threshold, or shaped by unmeasured contextual factors.

Considered together, these divergent measurement traditions indicate that the field has not yet converged on a validated, shared framework for operationalising parental engagement with digital nutrition interventions. Systematic evaluation of nutrition promotion websites and applications has previously called for more consistent reporting standards, yet subsequent studies continue to select measurement approaches based on platform convenience rather than theoretical justification (Zarnowiecki et al., 2020). Emerging analytic approaches such as digital phenotyping illustrate one promising direction for capturing engagement as a composite, individually differentiated pattern rather than a single aggregate number (González et al., 2022). Reconciling exposure based, completion based, and experience based measurement traditions remains an unresolved task with direct implications for how engagement should be linked to feeding related effectiveness.

Effectiveness Dynamics and Equity Considerations in Translating Parental Digital Engagement to Feeding Outcomes

The synthesis of effectiveness dynamics across the reviewed literature demonstrates that the translation of digital health interaction into empirical feeding outcomes depends heavily on achieving critical thresholds of active parental involvement. A primary challenge in evaluating these interventions lies in the fact that initial technology uptake rarely guarantees sustained usage, which consequently dampens the long-term impacts on children's dietary habits (Power et al., 2024). Non-empirical

conceptual analysis reveals that when parents transition from passive content consumption to active tracking, the probability of establishing stable responsive feeding patterns improves markedly. Scholars have noted that this translation mechanism operates unevenly across diverse socio-demographic groups, meaning that effectiveness cannot be evaluated independently of the socioeconomic structures shaping daily digital access (Eppes et al., 2022).

This uneven distribution of intervention benefits highlights the critical intersection between platform design, user engagement thresholds, and equity related outcomes among vulnerable family cohorts. To systematically unpack these dynamics, the extracted evidence has been structured around intervention effectiveness, dietary outcomes, and the specific socioeconomic factors that moderate parent participation.

Table 3. Synthesis of Digital Intervention Effectiveness Patterns, Dietary Outcomes, and Equity Moderation Parameters Across Diverse Parent Populations

Intervention Focus and Scope	Primary Nutrition and Feeding Outcomes	Key Equity and Moderating Contexts	Core Evidence Source
Mobile technology for family-based prevention targeting low-income cohorts	Enhanced responsive feeding practices and improved parental monitoring behaviors	Significant barriers related to time poverty, low digital literacy, and high attrition	Power et al. (2024)
Digital parent intervention promoting preschool healthy eating and activity	Incremental improvements in dietary structure and self-monitoring frequency	Tailoring requirements for low-income populations to reduce cognitive load	Bellows et al. (2025)
Systemic review of parent-based eHealth interventions for preschoolers	Improved feeding responsiveness alongside positive shifts in child dietary behaviors	Disproportionate participation from highly educated mothers in high-income countries	Zhou et al. (2023)
Digital child feeding guide minimizing controlling feeding behaviors	Reduction in maternal feeding anxiety and decreased reliance on restrictive feeding practices	Variable effectiveness driven by baseline parental stress and anxiety levels	Haycraft et al. (2020)
Systematic evaluation of digital nutrition promotion websites and applications	Positive shifts in parental feeding confidence and targeted child dietary choices	Access disparities linked to platform complexity and baseline technical proficiency	Zarnowiecki et al. (2020)
Mobile application intervention targeting maternal nutritional literacy	Enhanced maternal knowledge regarding stunting prevention and child feeding	Significant literacy barriers necessitating simplified interactive video components	Hasan et al. (2024)
Primary care eHealth obesity pilot developed for vulnerable pediatric patients	Modest behavioral changes in dietary choices and routine tracking compliance	Severe structural barriers including limited connectivity and device sharing	Yudkin et al. (2023)

Source: compiled by the authors based on effectiveness data, dietary outcomes, and equity parameters reported in Power et al. (2024), Bellows et al. (2025), Zhou et al. (2023), Haycraft et al. (2020), Zarnowiecki et al. (2020), Hasan et al. (2024), and Yudkin et al. (2023).

The evidence structured in Table 3 indicates that improvements are more frequently achieved in parental feeding cognitions and practices rather than in child anthropometric markers. Longitudinal tracking shows that reductions in restrictive practices and improvements in feeding anxiety require sustained platform interactions over multiple months (Haycraft et al., 2020). Conversely, static information repositories that lack interactive tailoring struggle to alter parental behavior, because they

fail to address the immediate behavioral friction points parents encounter during stressful mealtime routines. The thematic synthesis underscores that the capacity of a digital intervention to shift child fruit and vegetable intake remains tightly constrained by the baseline socioeconomic stability of the household (Bellows et al., 2025).

A major equity challenge highlighted by the data in Table 3 relates to the demographic profile of participants who successfully sustain high engagement trajectories. Systematic analysis indicates that the overwhelming majority of robust digital intervention evaluations predominantly retain highly educated, high-income mothers, thereby biasing current understandings of platform effectiveness (Zhou et al., 2023). When digital platforms are deployed within low-income contexts without modification, structural impediments like device sharing, unstable internet connectivity, and time poverty frequently cause rapid user drop-off. Consequently, interventions that appear highly effective in controlled research cohorts often exhibit diminished utility when transitioned into diverse public health systems (Zarnowiecki et al., 2020).

Addressing these digital divides requires a fundamental reorientation toward user-centered architectures that actively minimize cognitive load for marginalized caregivers. In contexts characterized by high rates of childhood stunting, maternal nutrition literacy can be enhanced if applications replace text-heavy modules with accessible, localized video guidance (Hasan et al., 2024). Incorporating supportive features such as automated low-cost text prompts helps maintain connection with vulnerable families who face routine technological disruptions. This shift from complex, interactive web environments to simple, multi-component mobile designs ensures that behavior change support remains accessible to parents who lack extensive digital literacy assets.

The integration of digital health tools within primary pediatric care represents a promising mechanism for bridging these equity gaps and stabilizing long-term user retention. Clinical pilot interventions targeting economically vulnerable pediatric patients demonstrate that linking digital tracking with routine provider check-ups enhances parental accountability and compliance (Yudkin et al., 2023). By positioning the digital tool as an extension of the clinical consultation rather than a standalone app, interventions leverage the established credibility of healthcare practitioners. This integrated approach mitigates the rapid engagement decay typical of consumer-facing health platforms, generating more reliable habits around dietary monitoring and responsive feeding.

The dynamic nature of parent-child interactions requires that future digital interventions adopt highly flexible, adaptive architectures rather than fixed content delivery schedules. Observational evidence confirms that parental engagement is not static, meaning that rigid text schedules or non-negotiable module pathways quickly alienate busy caregivers managing shifting family routines. Integrating behavioral feedback loops that automatically adjust message frequency based on user response data can prevent platform fatigue while sustaining parental interest over extended periods. Ensuring that these adaptive designs are systematically tested across diverse family configurations constitutes an essential step toward achieving public health impact.

Ultimately, the translation of digital health interventions into equitable early childhood nutrition improvements remains limited by a lack of diversity in sample recruitment and execution. The current reliance on self-selected, resource-rich samples obscures the specific operational failures that occur when interventions are introduced to low-income or minority populations. Future research must prioritize mixed-methods implementations that explicitly track equity metrics, tracking not only aggregate dietary changes but also how access barriers moderate those outcomes across diverse groups. Rebalancing the literature toward inclusive, context-aware digital design is necessary to ensure that digital health advancements do not inadvertently widen existing health disparities.

CONCLUSION

In conclusion, the synthesis of digital health interventions highlights that while diverse technological modalities successfully deliver tailored behavioral strategies, the translation of initial platform uptake into meaningful childhood nutrition improvements depends heavily on reaching critical thresholds of active parental engagement. The operationalization and measurement of this engagement reveal substantial inconsistencies between subjective self reports and objective analytics, which complicates the determination of exact dose response relationships. Furthermore, effectiveness dynamics are deeply intertwined with socio demographic moderation parameters, exposing a critical equity divide where resource constrained caregivers face disproportionate access barriers and attrition.

Addressing these challenges requires a systematic reorientation toward inclusive, low cognitive load designs and clinical integrations that sustain caregiver participation and ensure equitable health outcomes across all family demographics.

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