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A REVIEW ARTICLE

Methodological narrative review: Tools to measure fruit and vegetable consumption among toddlers ; challenges of measurement tools; variations in serving sizes and food preparation methods

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Abstract

Measurement of the consumption of fruit and vegetable accurately in toddlers is crucial for evaluating interventions to prevent obesity and promote healthy eating habits. Nevertheless, significant methodological limitations persist due to proxy reporting, variability in serving sizes, and diverse food preparation methods. To assess the tools currently used to measure fruit and vegetable consumption among toddlers, identify challenges associated with measurement accuracy, and examine how variability in food preparation methods and portion size impact assessment validity in this narrative review.This interpretive narrative review synthesized peer-reviewed evidence from PubMed/MEDLINE, Scopus, and Web of Science, using iterative searching and reference screening to map how tools are used to assess toddlers' fruit and vegetable intake and to interpret common measurement challenges related to portion size and food preparation. Conventional nutritional assessment techniques, such as FFQs and 24-hour recalls, are nevertheless vulnerable to proxy reporting mistakes, social desirability, and recollection bias. Digital photography and mobile applications are examples of emerging technologies that have the potential to enhance things but still need more testing. Skin carotenoid measurement is an example of an objective biomarker that shows potential as a substitute for validation problems in young infants. Significant variation in serving sizes and food preparation techniques (such as purees and mixed dishes) also significantly affects measurement accuracy and restricts cross-study comparisons.Measuring toddlers' fruit and vegetable consumption is still challenging, despite advancements in dietary assessment methods. The most effective approaches must balance accuracy, feasibility, and burden while taking developmental characteristics into account. To increase measurement accuracy and intervention evaluation, future research should focus on developing age-appropriate technological solutions, standardizing portion size estimation, improving proxy-report methods, and validating objective biomarkers.

1. Introduction

Studies on the measurement tools of fruit and vegetable consumption among toddlers were appeared as a critical field of investigation because of their impact on long-term health consequences and early childhood nutrition [1,2]. Recently, methods used to assess toddlers' fruit and vegetable intake have expanded beyond parent-reported FFQs and recalls to include emerging approaches such as reflection spectroscopy–based skin carotenoid assessment and app-supported recording, but their suitability and validation in this age group remain uneven [3,4], Measuring toddlers' fruit and vegetable consumption accurately is crucial for evaluating interventions or strategies to prevent obesity and promote healthy eating habits, as many children do not meet recommended amounts [5, 6]. Current tools like FFQs and 24-hour recalls are vulnerable to recall bias, social desirability, and errors caused by household caregivers' lack of knowledge about foods eaten outdoors [8,9].

Furthermore, objective biomarkers such skin carotenoid assays using reflection spectroscopy show potential but encounter validation issues in young children [10].

The most effective methods to balance feasibility, accuracy, and burden are still debated; some research supports non-invasive biomarkers, while others promote improved proxy-report

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techniques [11,12]. Potential misconceptions of dietary intake and detrimental evaluation of nutrition interventions are the outcomes of these gaps [13].

This review conceptually focuses on three main constructs: tools of dietary assessment (such as FFQs, recalls, and technological advancements), biomarkers of fruit and vegetable intake (such as skin carotenoid scores), and the impact of serving size and variability of food preparation on measurement accuracy [14,15,2].

The objectives of this review are to critically assess the instruments currently in use for measuring toddlers' consumption of fruits and vegetables in academic studies, find challenges with measurement accuracy, and to examine at how the variability of serving sizes and food preparation techniques impact assessment validity. By combining data on tool performance and contextual factors, this review seeks to close the knowledge gap and inform future studies and intervention strategies.

2. Methods

2.1. Study design and setting

This study was designed as an interpretive narrative review focusing on how fruit and vegetable intake is measured among toddlers (approximately 1–3 years). Evidence was identified through structured searches in PubMed/MEDLINE, Scopus, and Web of Science, and by screening reference lists of key methodological papers to capture additional relevant sources. The search terms were developed to retrieve literature on (a) toddlers and early childhood feeding, (b) tools used to assess fruit and vegetable intake (e.g., FFQs, parent-proxy recalls, food records, observation, digital image-based methods, and biomarkers), and (c) contextual measurement factors that affect validity in this age group, particularly portion/serving size estimation and food preparation forms (e.g., purees and mixed dishes). Consistent with a narrative review design, the goal was to map the range of tools, summarize recurring measurement challenges, and interpret why these challenges persist across settings rather than to estimate pooled effects.

2.2. Data collection procedure

2.2.1. Inclusion Criteria

Studies were included in the review if they met all the following criteria

2.2.2. Population

Focused on toddlers or preschool-aged children, defined primarily as 1–3 years, with studies including children up to 5 years considered eligible if results were applicable to toddler dietary assessment.

2.2.3. Outcome of interest

Reported measurement of fruit and/or vegetable consumption, either as a primary outcome or a clearly defined dietary component.

2.2.4. Methodological focus

Evaluated, validated, described, or applied dietary assessment tools relevant to measuring fruit and vegetable intake (e.g., FFQs, 24-hour recalls, food records, plate-waste methods, observation, digital image-based methods, or biomarkers).

2.2.5. Study type

Original research articles, validation studies, methodological papers, or systematic/narrative reviews published in peer-reviewed journals.

2.2.6. Publication characteristics

Published earlier and up to date studies which written in English

2.2.7. Exclusion Criteria

Studies were excluded if they met any of the following criteria

2.2.8. Age group mismatch

Focused exclusively on infants (<12 months) or older children/adolescents (>5 years) without methodological relevance to toddler dietary assessment.

2.2.9. Irrelevant outcomes

Examined dietary patterns or nutrient intake without specific consideration of fruit and/or vegetable consumption.

2.2.10. Non-methodological focus

Did not describe, evaluate, or apply a dietary assessment method (e.g., studies solely examining determinants of intake without describing measurement procedures).

2.2.11. Publication type

Conference abstracts, editorials, commentaries, dissertations, or grey literature without peer review.

3. Overview of Assessment Tools

Tools are discussed in unequal depth because their prominence in toddler fruit and vegetable intake research and their methodological implications are not equivalent. Greater attention is given to parent-proxy recalls and FFQs because they are the most frequently used approaches in this age group and they generate recurring validity problems (e.g., portion estimation and reporting bias). Emerging tools (digital image-based methods and biomarkers) are covered selectively to highlight where they specifically address, or introduce, measurement challenges relevant to fruit and vegetable intake.

3.1. Subjective traditional Methods

3.1.1. Parent-proxy 24-hour recalls (interviewer-administered or web-based)

Conducting 24-hour dietary recalls means encouraging participants to report all the foods and beverages they consumed in the past twenty-four hours or on the previous day. This is carried out by specially trained interviewers and requires specific skills to link the information to a food composition database. [16]. New methods have been developed recently, including long-term epidemiological studies, to enhance how dietary information is collected in major research. The National Cancer Institute in the United States created a self-administered, 24-hour dietary assessment tool (ASA24) [17], which is one of these tools, and it relies on the multi-pass technique used in national surveys, such as the Canadian Community Health Survey (CCHS)[18].

Researchers can take advantage of the ASA24 system, which has been customized for use in Canada[19], with links to the Canadian food database and adjustments to the food groups present in the country. The Automated Self-Administered 24-hour Dietary Assessment Tool (ASA24) achieved a response rate of approximately 35% in the initial recall and 59% in the follow-up, demonstrating its effectiveness in measuring children's dietary intake [20]. Although further studies are needed to improve its performance for younger children, the ASA24 tool remains very popular due to its ease of use and its adaptability to large population studies [20].

3.1.2. A Consolidated proxy-reporting limitations in toddlers

Proxy reporting is a structural constraint in toddler dietary assessment because intake is recorded by an adult rather than the child. The main threats to validity cluster into three recurring domains: (1) portion size estimation error, amplified by grazing, plate waste, and incomplete knowledge of amounts consumed; (2) imperfect recall and fragmented caregiving, where meals occur outside the reporter’s presence (e.g., daycare) and information must be reconstructed from menus or other caregivers; and (3) social desirability–driven misreporting, where foods perceived as unhealthy may be selectively underreported and fruit and vegetable intake may be overstated. These limitations

can distort absolute estimates and complicate comparisons across studies, particularly when fruit and vegetable intake is captured within mixed dishes or variable preparation forms.

The most fundamental limitations stem from relying on a parent or caregiver to report retrospectively on another person's intake, compounded by the physiological and social characteristics of young children:

3.1.2.1. Portion Size Estimation Error (PSEE)

Of all the proxy approaches for 24-hour dietary recall (24HR), this is the most consistent restriction [21,22]. A small child may graze or leave food on the plate [21], making it difficult for parents to measure how much food they eat. In a validation study of preschoolers (ages 2 to 5) using ASA24, it was discovered that although parents could reasonably recall the food items, the accuracy of portion size assessments was poor [23,24]. Due to parental underestimating portions, estimations of calorie and macronutrient consumption based on parental reports were typically greater than genuine (seen) intake[23,25].

3.1.2.2. Imperfect Memory and Shared Caregiving

This is particularly difficult when several people split feeding responsibilities, necessitating data gathering from several proxy reporters. [26,27,28]. For example, according to research, more than one in five parents of preschoolers reported skipping meals because they took place somewhere else (such at daycare) [29,30]. The mean number of interruptions (things reported but not ingested) during meals that parents were not present for was higher due to systematic bias in their estimates, even when they had access to menus [31,32].

3.1.2.3. Desirability in Society Bias (Misreporting)

Foods thought to be unhealthy may be underreported as a result of proxies' selective reporting. According to longitudinal proxy reports, children between the ages of 12 and 36 months consumed significantly more nutrient-poor foods such juice, soda, chocolate, and candies. According to one study that examined proxy-reported memories in European children between the ages of two and nine, parents who thought their child was overweight were more likely to underreport (UNR). The probability of UNR was negatively correlated with the inclusion of dietarily harmful foods in analytic models, indicating selective misreporting [32].

3.1.2.4. ASA24-Specific Challenges

When using the automated, web-based ASA24 tool specifically for children via proxy reporting, additional limitations arise:

3.1.2.5. Lack of Proxy-Specific Design

Because ASA24 was not developed for proxy-reporting, it could not be tailored to inquire explicitly about the foods and drinks that "your child had" rather than the foods and beverages that "you had" [20,33,34]. This constraint posed data cleaning issues, as some recollections had to be eliminated because parents accidentally recorded their own intake (e.g., excessive caffeine or alcohol levels) rather than the child's. To enhance ASA24's application, researchers propose producing a version that expressly enables proxy-reporting [20].

3.1.2.6. Low Response Rates and Selection Bias

Even though ASA24 is scalable, its implementation often has low initial response rates (e.g., 35% for the first recall), which introduces systematic selection bias and reduces the generalizability of results [20]. Particularly, there is an underrepresentation of data from vulnerable populations that might encounter technological or literacy barriers because those who complete the recall are usually those with higher family income and specific maternal ethnicities, and they are less likely to have children with high BMI z-scores [35,36].

3.1.3. Food Frequency Questionnaires (FFQs)

are widely recognized, conventional dietary assessment instruments that are commonly used in extensive epidemiological studies to record "usual" or habitual food consumption over time [37]. They are grouped with food records (diaries) and 24-hour dietary recalls in the larger context of

traditional evaluation, each of which has distinct trade-offs in terms of participant burden and accuracy [38].

FFQs are frequently preferred over other conventional approaches due to their affordability and comparatively minimal responder burden [39].

In contrast to 24-hour recalls, A single 24-hour recall offers a thorough "snapshot" of a particular day, but until it is performed several times, it cannot accurately assess daily variance or long-term routines. On the other hand, FFQs are expressly made to rate people according to their long-term consumption habits [40].

In contrast to Food Records, Weighed diet records, often known as food records, are regarded as the " gold standard" because to their real-time recording and less reliance on memory. They require a lot of resources, though, and the act of recording can lead participants to change their real eating habits [40,41]. FFQs create recollection bias while avoiding this "reactive" bias [41,42].

3.1.3.1. Overestimation and Methodological limitation

FFQs have a tendency to overstate absolute food and nutrient consumption. The difficulties proxy reporters (parents) have calculating portion sizes and accounting for plate waste is sometimes blamed for this overestimation [37]. For instance, research employing the Eating Assessment in Toddlers (EAT) FFQ discovered that the instrument continued to yield better absolute estimates than weighted diet records even when certain portion aids, such as a child's palm volume, were included [43,44].

3.1.3.2. Utility in Epidemiological and Clinical Contexts

FFQs are considered reliable and valid instruments for rating individuals within a group (e.g., identifying the highest vs lowest users of fiber or sugar) despite their lack of absolute precision. Investigating diet-disease links in big populations requires this skill. Traditional FFQ formulation usually entails using national survey data to select a food list that accounts for at least 80% of the variation in important nutrient intakes in order to ensure validity [45,46,47].

3.1.4. Food Diaries

While they are related to other traditional approaches such as 24-hour recalls and Food Frequency Questionnaires (FFQs), they are distinguished by their reliance on prospective, real-time recording rather than retrospectively implemented memory [40,44].

3.1.5. Methodological Strengths

The tool is considerably less prone to the memory oversights that afflict recalls and FFQs since reporters are trained to document material as it is consumed. [44,48].

Moreover, Because it uses real-time weighing of food items, the Weighed Diet Record (WDR) is known for its precision in collecting portion sizes [44].

More comes strengths, Multiple-day records, often lasting three to five days, are more effective at capturing daily variations in a child's food than a single 24-hour recall [40].

3.1.6. Variants and Technological Integration

3.1.6.1. Estimated vs. Weighed

In certain research, parents describe amounts using household measures in 3-day estimated dietary records (3DR) [49]. Others employ weighed records that span four or five days, which yield the most detailed information [50].

3.1.6.2. Record-Assisted Recalls

In certain protocols, a trained interviewer uses a journal as a "quick list" to help with a subsequent 24-hour recall; this effectively combines the two techniques to increase accuracy [15].

3.1.5.3. Digital Advancements

Texting, mobile apps, food photography, and other forms of technology are gradually replacing or supplementing traditional paper diaries. By examining "before and after" pictures of meals, these techniques enable investigators to calculate consumption [42].

3.1.5.4. Limitations and Participant Burden

Food diaries are the most resource-intensive traditional tools, despite their accuracy. Parents or other caregivers must put in a lot of time and effort to complete a thorough diary over several days. Because their participants were already very motivated about nutrition, studies such as the SEED trial particularly selected diaries [51].

However, One major disadvantage is that recording may be "reactive," which means the parent may change the child's real eating habits to make the record seem easier to document or healthier [52].

In addition, Food records are often linked to under-reporting because participants may remove items to lessen the effort of recording, whereas FFQs tend to overestimate intake [53]. Obtaining a complete record for children who are in the care of numerous informants (e.g., daycare workers, grandparents) is a special challenge. To guarantee that meals consumed away from home are recorded, researchers frequently distribute "food-fed by other adults" forms or secondary diaries to substitute caregivers; nevertheless, this further complicates data collection [54,55].

Despite these challenges, food diaries are nearly always utilized as the reference method for validating newer or shorter instruments because to their perceived accuracy. They serve as the standard by which the relative validity of NutricheQ, NutriSTEP, and other FFQs is assessed [56,57].

3.2. Nutritional Screening Tools for Toddlers

In the hierarchy of dietary assessment methodologies, screening tools occupy a specific niche designed for rapid identification of nutritional risk rather than the granular quantification of habitual intake. While traditional tools like Food Frequency Questionnaires (FFQs) and Weighed Diet Records provide the detailed data required for population research, screening tools are optimized for clinical and community settings where speed and early intervention are prioritized [71].

Nutritional Screening defined as the process of finding "any inappropriate dietary pattern that may compromise health," which includes both undernutrition (such as micronutrient deficiencies) and overnutrition (such as obesity), is known as nutrition screening. Its primary objective is to instantly recognize those who need immediate intervention or a thorough nutritional assessment. During the "first 1,000 days" of infancy, when established eating patterns frequently carry over into adulthood, these tools are of particular significance [74,68].

3.2.1. Major Screening Instruments for Toddlers

3.2.1.1. NutricheQ

For toddlers between the ages of 12 and 36 months, NutricheQ is an 18-item quiz and categorized to three parts , the first part for (iron and vitamin D status), second part for (other dietary imbalances, such as poor fruit/vegetable intake), and the final part for (future hazards from feeding patterns) comprise this part. It has been proven to be successful in detecting toddlers with reduced nutrient density and increased consumption of "non-core" foods in Jordan, Lebanon, and Ireland [58,59,60,65].

3.2.1.2. Nutri STEP (Nutrition Screening Tool for Every Preschooler)

There are age-specific variants of this 17-item survey for preschoolers (3–5 years) and toddlers (18–35 months) [57]. It addresses four different categories: sedentary behavior, physical activity, factors influencing intake, and food/fluid intake. When compared to evaluations by experienced dietitians, NutriSTEP is notable for its high sensitivity (95%) in identifying toddlers who are at high risk [63,64].

3.2.1.3. FLY-Kids

A more recent Dutch tool with ten items that creates a "dashboard" to direct discussions about lifestyle aspects like screen time and nutrition between parents and youth healthcare experts [60].

3.2.1.4. Toddler Dietary Questionnaire (TDQ)

This 19-item survey is used in Australia to determine how frequently core and non-core food groups were consumed during the preceding seven days [66,67].

Screening tools are frequently compared with conventional "test" methods,to highlight their distinct compromises.

While screening tools only take three to five minutes to complete, in contrast to Weighed Diet Records (WDR), the "alloyed gold standard" that depends on real-time weighing for high precision [68,69,70]. In addition, the majority of screening instruments are developed to rank people according to risk level rather than offering precise estimates of typical intake. FFQs are lengthier (often 60–120 items) and need more resources, even though they also seek to rate persons [70,71]. Finally, in congested clinical settings when medical professionals have little time to talk to patients about nutrition, screening instruments are frequently the only practical choice [71].

3.2.1.5. Methodological Challenges

Despite their utility, screening tools face systemic issues common to all proxy-reported methodologies. Toddlers lack the cognitive ability to self-report, requiring parents to act as proxy reporters, which introduces recall bias and social desirability bias [20,72]. Furthermore, many screening tools, including NutricheQ, demonstrate low internal reliability (Cronbach's alpha scores around 0.3 to 0.5), which researchers attribute to their multi-dimensional nature and the relatively small number of questions in each section [58,73].

4. Discussion

The current state of nutritional assessment instruments utilized for evaluating toddlers' consumption of fruits and vegetables between the ages of 12 and 36 months has been critically assessed in this methodological narrative review. A recurring conflict between scientific rigor and practical feasibility is revealed by the synthesis of the evidence, and no single instrument has emerged as being consistently more effective in all clinical and research contexts. Meanwhile, particular study goals, the availability of resources, and the consequences of compromise present in proxy-reported dietary data must all be taken into consideration when selecting an instrument.

In particular, the inevitable reliance on proxy reporters—usually parents or caregivers—who must either prospectively or retrospectively record another person's intake is a key finding shared by all approaches. The introduction of systematic biases severely compromises measurement validity. These issues are summarized in the consolidated proxy-reporting section (Section 3.1.1A), and they are illustrated below with examples from commonly used tools.[21,33]; where parents selectively underestimate unhealthy foods or overestimate fruits and vegetables to demonstrate a more favorable dietary profile [33,77].

These difficulties derive from broader concerns regarding the fundamental validity of proxy-reported data in early childhood nutrition research rather than just technological constraints. For example, research employing ASA24 for proxy reporting showed that parents could accurately recollect meal items but gave inaccurate portion sizes, which resulted in a systematic overestimation of macronutrient intake and calorie[8]. In a manner comparable to this, studies on children in Europe between the ages of two and nine showed that parents who thought their child was overweight were far more likely to underreport intake, with selective misreporting concentrating on nutrient-poor foods [28]. These results raise significant concerns regarding the construct validity of such measures since they imply that proxy-reported data may be more representative of parental attitudes and concerns around child feeding than actual nutritional consumption.

Conversely, weighed food diaries, which provide better portion size consistency through real-time weighing and less memory bias, continue to be the closest comparable estimate to a gold standard among conventional subjective methods [25,78,79]. However, their utilization is frequently restricted to exceptionally motivated samples due to its implementation's high participant burden and significant resource requirements [25,79]. Food diaries have a crucial drawback that could paradoxically lower ecological validity despite improved measurement precision: reactive bias, which occurs when the act of recording changes real eating behavior [53,81].

However, because of their implementation's high participant burden and substantial resource needs, its use is often limited to highly motivated populations. Reactive bias, which happens when the process of recording alters actual eating behavior, is a significant flaw in food diaries that could paradoxically reduce ecological validity despite greater measurement precision [53,81].

Additionally, Food Frequency Questionnaires (FFQs), which capture habitual eating habits over long periods of time with minimum resources, show the most practicality for large-scale research [57,82]. FFQs are useful for examining diet-disease links because they are good at ranking people within groups, despite their known tendency to overestimate absolute intake [57,82]. For instance, even when absolute estimations were higher than those from weighed records, the Eating Assessment in Toddlers (EAT) FFQ displayed adequate validity for ranking. This implies that relative rather than absolute evaluations of fruit and vegetable consumption may be the best application for FFQs [83].

Alternatively, a unique methodological niche is occupied by nutritional screening techniques such as NutricheQ and NutriSTEP, which prioritize quick risk identification over accurate intake estimation. The remarkable 95% sensitivity of NutriSTEP in identifying children at high risk shows how quick tools can aid in clinical decision-making [63,64]. However, due to their multi-dimensional structure and limited item sets, many screening instruments have low internal reliability (Cronbach's $\alpha = 0.3–0.5$), which raises challenges regarding measurement consistency [58,73].

Screening tools are particularly well-suited to demanding clinical settings where thorough nutritional assessment is impracticable due to their 3–5-minute completion duration [84]. However, this efficacy comes at the cost of precision; while screening methods can identify individuals who need assistance, they are not very good at identifying the precise dietary adjustments that are required [85]. Because of this restriction, screening tools must be used as gatekeepers rather than diagnostic tools in the hierarchy of nutritional assessments, necessitating follow-up with more thorough assessment techniques.

Looking forward, persistent measuring problems may be resolved by emerging technologies. While providing objective verification of meal items and portion quantities, digital photography and mobile applications lessen participant burden [86]. A non-invasive biomarker method that completely avoids proxy-reporting errors is reflection spectroscopy for skin carotenoid assessment [87]. There are still outstanding problems regarding the link between dermal carotenoid content and real fruit and vegetable intake in young children, who might have distinct metabolic profiles than adults, and the validation of skin carotenoid scores in toddlers [87].

There are challenges in using technology in nutritional assessment. Digital tools may worsen health inequities because they demand sufficient technological literacy and access. Additionally, combined dishes and different preparation techniques may be difficult for automated coding algorithms to handle. This is especially problematic for child diets, which frequently comprise pureed foods, combination meals, and culturally diverse preparations. Some automated systems' "black box" characteristics may also make the processing and interpretation of nutritional data less transparent [3,82,83].

Complicating matters further, the variance in child meal preparation techniques and portion amounts is a crucial yet frequently disregarded issue [84,85,86]. Toddler servings differ significantly depending on age, appetite, and developmental stage, in contrast to regular adult portions (86). It is challenging to separate distinct food groups for examination because parents often alter diets by pureeing, mixing, or combining components [87,88]. The measurement problem for a toddler eating

raw carrot sticks is very different from that of a toddler eating vegetable puree combined with pasta sauce [87].

The design of the measurement tool is significantly impacted by this preparation heterogeneity. Fresh, frozen, canned, and pureed forms—all of which have distinct nutrient profiles—may be confused in answers to FFQs that ask about "vegetables" without mentioning the manner of preparation [38]. In a similar vein, thorough probing is necessary for 24-hour recollections to record preparation techniques, which increases participant burden and interviewer training needs [38,89]. This problem is made more difficult by the lack of toddler-specific standard portion size standards, as the majority of tools rely on adult-formulated serving sizes that might not be suitable for young children [8,89].

Consequently, the methodological shortcomings found in this review directly affect how current work is interpreted and how future research is planned. Inconsistent results across studies may be explained by measurement error in exposure factors (fruit and vegetable intake), which attenuate correlations with health outcomes [65]. To triangulate estimates, researchers should be clear about these limits and, whenever feasible, use several complementary techniques [38].

The assessment technique selected for intervention research should be in line with the mechanism of action of the intervention. FFQs may be sufficient for evaluating interventions that target habitual dietary patterns, but more specific techniques, such as weighed records or observation, are needed for interventions that target portion sizes or particular meals [65,74]. Assessment timing in relation to intervention delivery is also crucial; if parents believe their child's food is being "tested," evaluations conducted immediately after the intervention may be more susceptible to social desirability bias [65,74].

The most practical method for routine nutritional surveillance in clinical practice is to use screening tools; positive screenings result in a referral for a thorough evaluation by registered dietitians. Clinicians should be cautious, nevertheless, that negative screening does not rule out nutritional issues, especially in areas where disclosure of feeding challenges may be suppressed due to social desirability bias [68,78,90,91].

To address these challenges, this review reveals several promising directions; First, present design restrictions would be addressed, and data quality would be improved by creating proxy-specific versions of automated tools such as ASA24. Second, there is an urgent need to validate biomarker techniques in toddler populations in order to develop non-invasive substitutes for proxy reporting. Third, uniformity across studies would be improved by the development of toddler-specific portion size atlases with visual aids showing typical serving sizes and preparation techniques. Additionally, Hybrid approaches that blend subjective and objective methods should be investigated as part of methodological innovation. For instance, combining parental FFQs with recurring biomarker evaluations may yield both objective validation and habitual consumption patterns. In a same vein, adding digital pictures to food diaries lessens the workload while preserving detail. In the future, more precise automatic categorization of mixed plates and culturally diverse foods may be possible thanks to machine learning algorithms trained on big datasets of toddler nutritional intake. Lastly, measurement equity requires greater attention. The validity of current tools is disproportionately found among populations with high levels of health literacy and resources. To ensure that nutritional research and monitoring do not reinforce current health inequities, it is crucial to develop and validate culturally appropriate instruments for a variety of populations, such as low-income households, immigrant communities, and non-English-speaking individuals.

5. Conclusion

Measuring toddlers' fruit and vegetable intake remains methodologically constrained because most approaches depend on adult proxy reporting in a context where portion size, plate waste, and mixed or pureed preparations are common. In practice, the central implication of this review is that tool choice should be driven by the purpose of measurement: tools that are feasible at scale (e.g., FFQs and proxy recalls) may support ranking or surveillance, but they are less defensible for precise

absolute intake estimates without additional supports. Emerging approaches (digital image–based methods and non-invasive biomarkers) are promising mainly because they can reduce reliance on recall and improve objectivity, but their toddler-specific validation and equity of use require more evidence. Future work should prioritize toddler-appropriate portion-size supports, clearer capture of preparation forms in mixed dishes, and triangulation strategies that pair subjective tools with objective indicators where feasible to strengthen interpretation of intervention outcomes.

Conflict of Interest

There are no financial, personal, or professional conflicts of interest to declare.

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مراجعة منهجية سردية: أدوات قياس استهلاك الفواكه والخضروات بين الأطفال الصغار؛ تحديات أدوات القياس؛ اختلافات أحجام الحصص وطرق تحضير الطعام

الملخص

إنّ قياس استهلاك الفواكه والخضروات بدقة لدى الأطفال الصغار يُعدّ أمرًا ضروريًا لتقييم التدخلات الهادفة إلى الوقاية من السمنة وتعزيز العادات الغذائية الصحية. ومع ذلك، ما تزال توجد قيود منهجية مهمّة بسبب الإبلاغ بالوكالة، وتباين أحجام الحصص، وتعدد طرق إعداد الطعام.الأهداف: تهدف هذه المراجعة السردية إلى تقييم الأدوات المستخدمة حاليًا لقياس استهلاك الفواكه والخضروات لدى الأطفال الصغار، وتحديد التحديات المرتبطة بدقة القياس، وفحص أثر تباين طرق إعداد الطعام وحجم الحصة على صلاحية التقييم. اعتمدت هذه المراجعة السردية التفسيرية على تجميع أدلة محكّمة من قواعد بيانات PubMed/MEDLINE وScopus وWeb of Science، باستخدام بحث تكراري وفحص قوائم المراجع لرسم خريطة لاستخدام أدوات القياس في تقييم تناول الفواكه والخضروات لدى الأطفال الصغار، وتفسير التحديات الشائعة المرتبطة بحجم الحصة وطرق إعداد الطعام.

تظلّ تقنيات التقييم الغذائي التقليدية، مثل استبيانات تكرار الغذاء (FFQs) واستدعاءات 24 ساعة، عرضةً لأخطاء الإبلاغ بالوكالة، وللرغبة الاجتماعية، ولتحيز التذكر. كما تُعدّ التقنيات الناشئة مثل التصوير الرقمي وتطبيقات الهاتف المحمول واعدةً في تحسين القياس، لكنها ما تزال تحتاج إلى اختبارات إضافية. ويُظهر قياس الكاروتينات في الجلد بوصفه مؤشرًا حيويًا موضوعيًا إمكانيةً واعدةً كبديل لمعالجة مشكلات التحقق، إلا أنّ تباين أحجام الحصص وطرائق إعداد الطعام (مثل الأطعمة المهروسة والأطباق المختلطة) يؤثر بصورة ملحوظة في دقة القياس ويحدّ من قابلية المقارنة بين الدراسات.ما يزال قياس استهلاك الأطفال الصغار للفواكه والخضروات يمثل تحديًا رغم التطورات في أساليب التقييم الغذائي. وتحتاج المقاربات الأكثر فاعلية إلى موازنة الدقة وقابلية التطبيق وعبء القياس مع مراعاة الخصائص النمائية لهذه الفئة. وينبغي أن تركز البحوث المستقبلية على تطوير حلول تقنية ملائمة للعمر، وتوحيد تقدير أحجام الحصص، وتحسين أساليب الإبلاغ بالوكالة، والتحقق من صلاحية المؤشرات الحيوية الموضوعية.

الكلمات المفتاحية: التقييم الغذائي، الأطفال الصغار، تناول الفواكه والخضروات، أدوات القياس، حجم الحصة، إعداد الطعام، المؤشرات الحيوية، منهجية التغذية