Predictive Models and Tools for Early Detection of Stunting in Children: Systematic Review

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Predictive Models and Tools for Early Detection of Stunting in Children: Systematic Review

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Abstract

Stunting is a common health issue among children worldwide. The causes of stunting in middle-income countries differ from those in wealthy countries. Algorithms or useful variables can determine the predictive factors for stunting, enabling people to identify the risks of stunting in children. The method used was a systematic review. Using predetermined keywords, the researcher conducted a literature search across multiple databases, including PubMed, ProQuest, Emerald, and Springer. The present systematic review is under the guidance of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRIS-MA), without a meta-analysis. We reviewed all the articles and found only 13 that met the inclusion criteria for this research. The prevalence of stunting based on age varies greatly, and the majority occurs in developing countries. Most factors causing stunting in the literature are gender, maternal education, economic status, and number of family members. Anthropometry is one of the measurement tools used to assess the height and weight of children. Another measuring tool that is also used is the Composite Index of Anthropometric Failure (CIAF), Meiru Chart, WHO lookup tables, and WHO Growth charts to figure out if a child will be stunted.Conclusion: Using predictive models and tools can facilitate early detection of stunting, enabling timely interventions to mitigate its long-term effects on child health and development.

Keyword: Anthropometry; Predictive Models and Tools; Stunting

INTRODUCTION (12pt, all caps, Time News Roman, Bold, 1,5 space)

Stunting is currently one of the health issues attracting global attention and affecting children. Stunting is a condition in which a child's growth is retarded as a result of poor nutrition, leading to a shorter height than their friends (Simbolon et al., 2019; UNICEF et al., 2023; Yani et al., 2023). Additionally, does stunting cause a child to be shorter than their friends? It also has long-term effects and significant complications that can affect the next generation if not prevented and identified immediately (Aychiluhm et al., 2021; Yani et al., 2023).

Stunting is the highest prevalence globally, found in Asia (Southern Asia), reaching 78.6 million. The prevalence of stunting in Africa from 2012 to 2022 increased from 43 million to 63.1 million (UNICEF et al., 2023). The prevalence of stunting in Indonesia in 2024 reached 30.5%, a decrease from the previous year, 2023 when it was 34.6% (WHO, 2025).

Stunting is caused by poor nutritional status but is also caused by multiple factors such as family, child, and environmental factors (Afework et al., 2021; Chapagain et al., 2023; Huriah & Nurjannah, 2020). The family factors determine the baby's nutrition in the first 1000 days after birth. Stunting is also influenced by the mother's and family's knowledge about the baby's nutrition (Bantie et al., 2021; Tamrat et al., 2024). Maternal education affects the risk of stunting, where children of mothers with low education levels have a 1.6 times higher risk of stunting compared to children of mothers with higher education levels (Suratri et al., 2023).

In adherence to the research series, the study findings state that a relationship exists between the mother's level of education and the prevalence of stunting (Laksono, Sukoco, et al., 2022; Laksono, Wulandari, et al., 2022). Maternal education influences parenting patterns, including the daily nutritional management of children. Mothers with a good education can receive information and enhance their understanding and knowledge about child-rearing. Therefore, a mother's education is closely related to her understanding of implementing child-rearing practices and the child's nutritional status.

Factors in children such as gender, medical history, age, birth weight, and milk consumption can influence stunting (Kebede et al., 2021; Mkungudza et al., 2024). According to the research by Suratri et al., the factors influencing stunting are the age of the child, 24-35 months, maternal education, and children living in rural areas (Suratri et al., 2023). The age of 24-35 months is crucial as it is the transition phase from infancy to toddlerhood. The age of 24-35 months is essential because toddlers are vulnerable to infections or malnutrition due to significant changes in food texture (Simbolon et al., 2019).

Environmental factors are often associated with stunting, such as the ease of access to clean water used for daily needs, which affects the cleanliness of utensils and food consumed (Bazie et al., 2021; Mengesha et al., 2021). In addition, the place of residence can also pose a risk of causing stunting. Research conducted by Gebru et al. shows that children whose parents live in rural areas have a higher experience of stunting compared to those who live in urban areas due to the presence of a comprehensive healthcare system and easier access to healthcare facilities (Fantay Gebru et al., 2019). This research is in line with the study conducted by Tekile et al., which states that urban children generally have better nutritional status than rural children. Urban resident's environmental conditions, choices, and opportunities differ significantly from those of rural residents, ranging from job conditions to social and family networks and access to healthcare and other services (Tekile et al., 2019). Other literature also

mentions economic status and income, number of family members, and comorbid diseases as factors causing stunting (Muche, Gezie, et al., 2021; Tamrat et al., 2024).

Based on the explanation above, many factors causing stunting are already known. However, the occurrence of stunting in children in Indonesia has its own determining factors that may differ from stunting in other developing countries and even developed countries. This condition could be influenced by geographical location, climate, and culture. Generally, the assessment of stunting occurrence and its causes is conducted using anthropometric measurement tools and questionnaires. Anthropometric indices are used to assess physical growth and body weight. Body weight according to age, height/length according to age, body weight according to height/length, and BMI according to age can be used for preschool children (aged < 5 years), school-aged children (5–11 years), and adolescents (aged 12–18 years). All these indices are expressed as z-scores calculated according to WHO standards (de Onis et al., 2012).

The research conducted by Yisak et al. used anthropometric instruments to determine body mass index (BMI). Measurements were taken using a wooden length board, a vertical wooden height board with a removable sliding head, and a tape measure for the child's upper arm circumference. The body length of children under two years old is measured barefoot using a horizontal wooden board with the baby supine (Yisak et al., 2021). In another study that also used anthropometry with the SECA digital measuring instrument from Germany, each child was examined without shoes, with minimal clothing, with empty pockets, and without earrings and measured twice. The average weight or height was taken, and strict supervision was ensured during the measurement (Bazie et al., 2021). In addition to anthropometry, the measuring tools used in the research conducted by Chanyarungronjn et al. to detect stunting were the MEIRU chart, WHO lookup tables, and WHO Growth charts (Chanyarungrojn et al., 2023).

In addition to the prevalence of stunting, an assessment of the risk factors for stunting is also necessary. There is a need to assess stunting risk factors to help raise public awareness of the risk of stunting in children (Mahmudiono et al., 2018). The stunting risk factor assessment system can be determined through algorithms or early detection models using variables that can detect the risk of stunting in children (Hasegawa et al., 2017). An assessment system can classify stunting risk by determining variables, making it easier to classify. The assessment system can classify high-risk and low-risk groups for stunting, built based on

existing determinant data so that the risk of stunting can be estimated earlier. Therefore, to prevent and detect the occurrence of stunting and reduce its impact, there is a need for programs or the development of systems to prevent stunting.

METHODS (12pt, all caps, Time News Roman, Bold, 1,5 space)

The method used in writing this article is systematic review with guidance of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRIS-MA), without a meta-analysis. This systematic review aims to identify all relevant studies on the prediction tools used to determine the prevalence and related factors of stunting. We used the SPIDER method to define this study's inclusion and exclusion criteria. The research sample is infants, children, adolescents, and toddlers. The inclusion criteria include prevalence, risk factors, and stunting measurement tools. The types of research include cross-sectional and case studies, with full text available in English. The exclusion criteria in this study are review articles, topics that are not relevant, unavailable articles, and articles without full text.

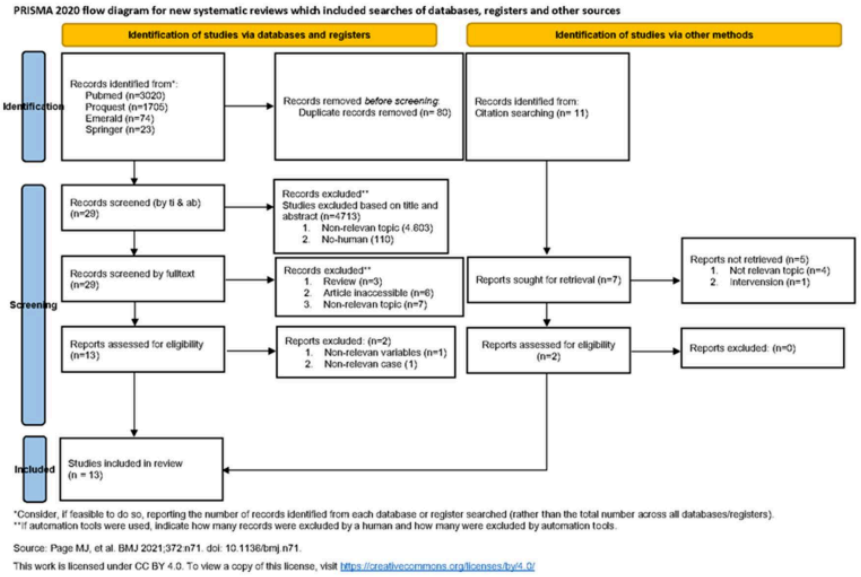

Figure 1. PRISMA 2020 flow diagram

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The literature search was conducted through the PubMed, Proquest, Emerald, and Springer databases, with data collection starting in November 2024. The literature search used the main keywords: Toddlers* OR Children* AND Predictive Model and Tools OR Prediction* AND Stunting OR Growth Disorder. We refined the searches based on the inclusion criteria, focusing on publications from the last five years (2019-2024).

The Mendeley application system imported the references that emerged from the database searches. Screening of title and abstract was carried out on 4.742. A total of 13 articles were decided to be eligible for full-text review. Figure 1 shows a PRIS-MA flow diagram that illustrates the entire selection process. Studies that didn't meet the inclusion criteria were rejected for inclusion.

The articles included in this assessment use different methodologies so that the authors conduct a critical appraisal to determine the quality of the articles using the instrument tool from JBI (Joana Briggs Institute). The Critical Appraisal Tool is explicitly used to evaluate specific articles. 13 articles were found to be related to the authors' identification of stunting prediction tools.

RESULTS

The search results from the database that have been conducted can be seen in the PRIS-MA flow diagram (Figure 1). A total of 4.822 articles were retrieved using the selected keywords. A total of 80 were excluded based on duplicate screening results, and 4,713 were excluded due to irrelevant topics and not being human research, leaving 29 literature. Full-text screening was then conducted, and 16 were excluded due to being review articles, inaccessible articles, and irrelevant topics, leaving 13 remaining. Out of the 13, we excluded two articles based on irrelevant variables, which left us with 11 pieces of literature. We conducted another literature search, which yielded 11 additional pieces of literature. Nine pieces of literature were excluded due to irrelevant topics and intervention studies, leaving two and 13 eligible articles remaining.

Table 1. Summary of Review Articles

No	Authors/Year	Design	Setting/Country	Characteristic Sample	Result
1	Demsa Simbolon et al/2019	Cross-Sectional	The study setting is based on the IFLS 2007 research location, Indonesia	3596 toddlers 1-5 years old	a. Prevalence * was higher in 12-23 months and 24-35 months of age. b. Prediction model of stunting prevention and control

					Birth Weight. Number of childs, Gender, Birth Age, Mother's Height, Immunization Status, Mother's Education, Family Residence, Fe tablet use c. The scoring obtained cut-off point >13.5 as a detection of stunting risk with a sensitivity of 61.9%, spesificity of 60.9%, value of area under the curve 65.5% d. Data collection used a structural questionnaire developed and modified for IFLS 2007
2	Masrul et al/2020	Case-control	Research location in West Sumatera Province, Indonesian	40 children (case group stunting) and 40 children (non-stunting)	a. The scoring system for analyzing stunting risk is based on predictors of mother's level education, birth weight, exclusive breastfeeding, the child's appatite and parenting style. b. The cut-off point in grouping high risk of stunting and low risk of stunting is based on a total score of ≥ 4 (high risk of stunting) and < 4 (low risk of stunting) c. The accurasy of scoring system in prediction of stunting risk among children with a sensitivity of 70.0% and specificity of 90.0%.
3	Amare Muche et al/2021	Cross-Sectional	Community Based/Ethiopia	8117 Children Age 6-59 months	a. Prevalence of stunting Stunting (41.20%) Moderate stunting (22.41%) Severe stunting (18.79%)

					b. Predictors of stunting Sex of child, Child age, Type of birth, Anemia status of the child, History of fever in the last 2 weeks, Education level of mother, Maternal BMI, Maternal height, Birth interval, Family wealth c. Measurement tools Anthropometric and Demogrhapic and Health Survey (DHS)
4	Hiwot Yisak et al/2021	Cross-Sectional	Based on all elementary school in the five urban special districts of South Gondar Zone/Ethiopia	300 children Aged 6-12 years	The prevalence of stunting, wasting, and underweight was 11%, 6.3% and 11.4%, respectively. b. Factors associated with stunting Milk comsumption habit, how often you use soap during hand washing and Occasionally c. Data collection used questionnaire and anthropometric measurement
5	Asres Mengesa et al/2021	Cross-Sectional	A community-based in Wonago district, Gedeo zone, Southern Ethiopia	660 Children Children under five years of age	a. Data Collestion tools A close ended questionnaire and Anthropometric measurement b. Prevalence of stunting among children under five years of age was 37.7% c. Predictors of stunting Family size less than five, Age less than 6 months, Rich wealth status, Drinking water like river water, Presence of two or more under five children

					in the household, Undiversified diet, Household food insecurity
6	Getaw Walle Bazie et al/2021	Cross-Sectional	A school-based Kutaber district, Northeast Ethiopia	341 Children primary school children Living at least for 6 months prior to the study in the district	a. Data collection Questionnaire was used to collect sociodemographic and dietary data and anthropometric b. Prevalence of stunting was found to be 14.1% c. Predictors of stunting Family size, washing hands less frequently before eating, Intestinal parasitic infection
7	Damitie Kebede et al/2021	Cross-Sectional	A school-based. There were six primary schools, six junior schools, one high school and one preparatory school in Finote Selam Town, Northwest Ethiopia	Adolescents students Aged 10-19 in public primary and secondary schools	a. Data collection Questionnaires and Anthropometric b. Prevalence Stunting (21.8%) Thinness (16.9%) c. Factors Associated with stunting Sex, Place of residence, Family monthly income, Dietary diversity
8	Ram Chapagain et al/2023	Cross-Sectional	Kanti Children's Hospital (KCH) in Nepal.	Children and adolescents aged 0–15 years visiting either the inpatient or outpatient	a. The prevalence: Stunting (25.9%) Wasting (17.3% and 24.0%) b. Predictors of nutritional status Food insecurity (wasting and stunting), Chronic medical conditions (wasting and stunting), Wealth Index (stunting), Ethnicity (wasting), Nutritional Assesment used anthropometric, Socio-demographics used questionnaires
9	Meseret Tamrat Gebretsadik et al/2023	Cross-Sectional	Community Based, was conducted in the	Mother–child pairs aged 6–23 months who	a. Data Collecting tools

			Rural Kersa district, Jimma zone, Southwest Ethiopia	were residents in theselected kebeles for more than 6 months	Questionnaire and Anthropometric measurement and Composite index of anthropomentric failure (CIAF) b. Prevalence of undernutrition was 57.3% among children aged 6-23 months c. Factors aasociated Child sex, Mother education, Birth order, Family Size, Comorbidity
10	Jonathan Mkungudza et al/2024	Cross-Sectional	Sab-Saharan Africa, specifically in Malawi	Children aged 0-59 months	Risk factors selected by all variable selection models include household wealth index, age of the child, household size, type of birth (singleton/multiple births), and birth weight.
11	Pannapat Amy Chanyarungronjn et al et/2023	Cross-Sectional	Area 25, Lilongwe, Malawi, one of MEIRU's established Demographic Surveillance Sites (DSS). It is a periurban area, with epidemiological and demographic characteristics typical of many other lowand middle-income countries, Malawi, Afrika	244 participants Aged 8-19 years (children and adolescents)	a. Assessment of stunting status: The MEIRU chart WHO lookup tables WHO Growth charts b. Diagnostic accuracy of each test method around HAZ-2 (stunting) Sensitivity (MEIRU 97,6; WHO lookup table 98,8; WHO growth chart 69,7) Specificity (MEIRU 96,3; WHO lookup table 61,7; WHO growth chart 71,2) Agreement (MEIRU 98,7; WHO lookup table 99,0; WHO growth chart 81,1) Kappa (MEIRU 0,93; WHO lookup table 0,51; WHO growth chart 0,39)
12	Budiailmiawan et al/2024	Cross-Sectional	Public Health Centres in the Public Health office in the Sukabumi	210 children were confirmed to be stunted Aged 1 – 24 months	a. Data collection Questioner Instrument, Anthropometric measurement, Biochemical and

			Regency area, North Maluku, and Teruwai Village, Central West Nusa Tenggara Regency, West Nusa Tenggara, Indonesia		haematology measurement b. Two hundred and ten stunted children were identified with various anaemias and comorbidities
13	Huda J Mhamad et al/2024	Cross-Sectional	The urban areas in Halabja Governorate of the Kurdistan Region, Iraq	646 Children Aged 4 to 5 years old	a. The prevalence of stunting was 7.9% b. Data Collection Structured questionnaire form from the children's parents including the following questions: demographics of children and parents, gestational age, type of feeding during the first two years of life, complementary feeding time, educational level of parents, family size, and socio-economic status. Anthropometric measurements for height and weight

DISCUSSION

Prevalence of Stunting

The literature review shows that the prevalence of stunting based on age varies greatly. The prevalence of stunting in the age group of 0-15 years (25.9%) at Kanti Children's Hospital Nepal, in the age group of 6-23 months (57.3%) in rural Kersa, Ethiopia, and the prevalence of stunting in children under 5 years old (37.3%) in Wonago, Ethiopia. The prevalence of stunting in children aged 4-5 years (7.9%) in Urban Halabi Iraq, ages 6-12 years (11%) occurs in primary schools in urban Ethiopia, ages 10-19 years (21.8%) among elementary, middle, and high school children in Finote Selam, Ethiopia. The prevalence of stunting in Indonesia was 24.4% in 2021, but it decreased to 21.5% in 2022. The Ministry of Health has established a target to reduce stunting to 14% by 2024. Thus, efforts to prevent and manage stunting must continue to incorporate a variety of cross-sectoral and interdisciplinary approaches (Kemenkes, 2023).

Risk Factors

The most frequently mentioned factors causing stunting in the literature are gender (Kebede et al., 2021; Muche, Gezie, et al., 2021; Simbolon et al., 2019; Tamrat et al., 2024), maternal education (Masrul et al., 2020; Muche, Gezie, et al., 2021; Simbolon et al., 2019; Tamrat et al., 2024), and economic status (Chapagain et al., 2023; Kebede et al., 2021; Mengesha et al., 2021; Mhamad et al., 2024) and number of family members (Bazie et al., 2021; Mengesha et al., 2021; Mhamad et al., 2024; Tamrat et al., 2024).

The most often mentioned factors in the article are some of the ones listed above. Other factors that are also presented are birth weight, age of the child, immunization status, exclusively breastfeeding, parenting style, milk consumption habit, how often you use soap during hand washing and occasionally, place of residence, and dietary diversity and comorbidity (Bazie et al., 2021; Kebede et al., 2021; Masrul et al., 2020; Mengesha et al., 2021; Mhamad et al., 2024; Muche, Gezie, et al., 2021; Simbolon et al., 2019; Tamrat et al., 2024).

According to Masrul et al.'s research in Indonesia, factors affecting the incidence of stunting in children under the age of five in West Sumatra Province include the mother's education level, mother's employment status, socioeconomic status, birth weight, exclusive breastfeeding, history of infectious diseases, child's appetite, and parenting style (Masrul et al., 2020). Study literature conducted by Togatorop et al. about the factors associated with stunting in children aged 0-24 months consists of child, maternal, and family factors. Child factors include birth weight, birth length, gender, and age. These factors are unchangeable, especially gender and age. The mother's factor is a crucial cause of stunting occurrences. Therefore, mothers become the primary target in efforts to prevent stunting. Starting from the mother's pregnancy condition, the mother's readiness for pregnancy, the mother's nutrition before and during pregnancy, and proper care during childbirth and child care. Family factors are the main contributors to stunting, including low levels of education and poverty within households. They are two main factors that lead to the quality and quantity of food and water, resulting in inadequate nutrition (Togatorop et al., 2024).

Measurement tools of stunting

Literature studies analyze the tools used to assess stunting and the risk factors causing stunting. All the literature mentions that anthropometry is the measurement tool used to assess the height and weight of children (Bazie et al., 2021; Budiailmiawan et al., 2024; Chapagain et al., 2023; Kebede et al., 2021; Mengesha et al., 2021; Mhamad et al., 2024; Muche, Gezie, et

al., 2021; Simbolon et al., 2019; Yisak et al., 2021). Another measuring tool that is also used is the Composite Index of Anthropometric Failure (CIAF), Meiru Chart, WHO lookup tables, WHO Growth charts, and biochemical and hematological tests to measure anemia in children. Meanwhile, to determine demographics, gestational age, types of food provided, maternal education, number of people in the family, and socio-economic status or other necessary data, instruments in the form of questionnaires, both validated and developed, were used.

Anthropometric measurements are body measurements viewed numerically without performing invasive procedures. According to the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), anthropometric measurements can provide valid assessment results regarding nutritional status from childhood to adulthood (Casadei & Kiel, 2022). Anthropometric measurements also evaluate general health status, nutritional adequacy, and children's growth and development patterns. Various anthropometric indicators are used to assess nutritional status, including height, weight, BMI, upper arm circumference (UAC), z-scores for BMI by age, z-scores for weight by age, z-scores for height by age, and the results vary among studies according to the standards used for assessment (Santra et al., 2023). In Indonesia, research on stunting generally uses anthropometry as a measurement tool. The study conducted by Aryanti et al. used anthropometry as a measurement tool for the nutritional status of girls aged 13-15 years. Based on the measurement results, it was found that the prevalence of girls aged 13-15 years reached 25.1% in Galesong District, South Sulawesi, Indonesia (Aryanti et al., 2024). Another study by Budiailmiawan et al. performed anthropometric measurements on stunted children, including the children's and their parents' weight and height. The measurements were conducted by professional healthcare personnel using the Endo Anthropometric Kit 10 (Endo International plc, Dublin, Ireland) (Budiailmiawan et al., 2024).

Stunting research is also widely conducted in Ethiopia. In addition to using anthropometric measurements conducted with conventional indices, measurements are also carried out by applying CIAF, which is an anthropometric index that combines three indices: weight-for-age, height/length-for-age, and weight-for-height/length to determine the nutritional status of children under five years old. CIAF is an anthropometric index that combines the three indices mentioned above (LAZ, WAZ, and WHZ) to estimate the overall prevalence of malnutrition as a single measure among children aged 6–23 months. The classification of malnutrition based on CIAF is categorized into seven groups: Group A (no failure), Group B (only thin), Group C (thin and underweight), Group D (short, thin, and

underweight), Group E (short and underweight), Group F (only short), and Group Y (only underweight) (Tamrat et al., 2024).

The research conducted by Muche et al. on predictors of stunting in children aged 6–59 months used anthropometry to measure the height and weight of the children. Children under 24 months are measured supine using a locally made measuring board with a vertical wooden base and a movable head. Children aged ≤ 24 months are measured in an upright position. Nutritional status indicators with a Z-score of less than -2 SD from the median are considered stunting (Yunitasari et al., 2022). The results of the study found a stunting prevalence of 41.20% in children aged 6-59 months, with predictors of stunting including gender, age of the child, type of delivery, anemia in the child, history of fever, maternal education, maternal BMI, birth weight, and economic status (Muche, Melaku, et al., 2021). These results are in line with the research conducted by Yisak et al. to determine the prevalence and determinants of underweight, stunting, and wasting in school-aged children. Data collection was conducted using questionnaires to gather demographic, socio-economics, food intake, and hygiene data, as well as anthropometric measurements of children's height and weight. The research results show that the prevalence of stunting is 11%, underweight is 11.40%, and wasting is 6.3%, with factors influencing stunting being never consuming milk and never using soap when washing hands (Yisak et al., 2021).

In Malawi, Africa, a study was conducted to evaluate the accuracy of stunting diagnostics, namely the MEIRU wallchart, traditional lookup tables, and traditional growth charts. The MEIRU wallchart measurement is a tool in the form of a wallboard with graphs corresponding to specific ages (8-19 years). Each graph is given a color code: orange for very short stature (HAZ -4 to <-3), yellow for short stature (HAZ -3 to <-2), and green for normal stature (HAZ ≥2). The results of the diagnostic accuracy estimation show that the MEIRU wall diagram has an overall agreement rate of 95.5%, the WHO lookup tables chart has an agreement rate of 59.4%, and the WHO growth chart has an agreement rate of 61.9%. Participants and healthcare workers greatly preferred the MEIRU chart to the traditional method (Chanyarungrojn et al., 2023).

CONCLUSIONS

Predictive models and tools can facilitate early detection of stunting, enabling timely interventions to mitigate its long-term effects on child health and development.

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