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Artificial Intelligence for Diagnosing Child Stunting: A Systematic Literature Review

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Abstract. Stunting in children due to malnutrition remains a global concern with the World Health Organization (WHO) reporting a prevalence of 22% in 2020, exceeding the maximum limit of 20% set by the organization. Artificial intelligence (AI) has been utilized in several studies to diagnose, predict, and plan nutrition for stunted children. However, there is a lack of research on direct stunting diagnosis, which can benefit parents who cannot afford to take their children to medical professionals for regular check-ups. This study aims to review previous research on stunting and commonly used algorithms for diagnosing the condition. The study follows a systematic review process with the PRISMA protocol for quality research article selection. The results of this systematic review are expected to facilitate the development of more stunting diagnosis systems to assist parents and health workers.

Keywords: Artificial intelligence, Expert system, Diagnose, Child stunting

1. Introduction

Child stunting is a problem that occurs because of chronic malnutrition in the first 1000 days of life (Sutoyo, Widodo and Rochim, 2021). Globally, World Health Organization (WHO) confirmed that 22% of all children under 5 years were stunted in 2020. Especially Indonesia, in 2018 was globally ranked fifth highest stunting prevalence in children under five years old with 30.8% (Hadi, 2021; Ratna Utari *et al.*, 2021). Latest data from the Ministry of Health of Indonesia, Indonesia's stunting prevalence has decreased to 24,4% in 2021 (Ministry of Health of Indonesia, 2021). Even though it has decreased, this prevalence is still above the maximum limit of stunting prevalence by WHO, which is 20%.

The potential causes of stunting are the nutritional status of the mother, the practice of complementary feeding, breastfeeding practices, and exposure to infections and related environmental factors such as health services, education, food systems, and water and sanitation infrastructure and services (Beal *et al.*, 2018). So, to prevent children from stunting, their parents must raise awareness for their needs and fulfil it. In addition, parents should routinely check the condition of their child's growth and development with the doctor so they can monitor their child's growth and development. But, not every parent can bring their child to the doctor. Therefore, parents need something that can help and assist them monitor their child's growth and development.

Nowadays, technology has been developed to significant progress. Classical statistical models have been used to diagnose child stunting over the years. The shortcoming of these methods was not robust when there was multi-correlation among variables. Artificial intelligence (AI) was compared to classical model can overcome the multi-correlation challenges and have been shown to be superior when solving classification problems such as stunting diagnosis (Chilyabanyama *et al.*, 2022). Expert system (ES) is an AI software that uses knowledge stored in a knowledge base to solve problems typically required by human experts and provide explanations about the conclusion or advice. Not many studies have conducted a diagnosis of stunting with ES. The majority of past research is machine learning for the prediction of stunting or malnutrition. Although the use of ES for the diagnosis of stunting is very small, it is widely used for diagnostics and decision support systems. Examples of previous research are diagnostics of eye disease, disease of tomatoes, disease of quail, diagnosis of drug users and their types, and many more. The purpose of this systematic literature review is to review the recent literature to determine what has been studied and what can be concluded about artificial intelligence to diagnose child stunting that can be used to assist parents to monitor their children.

2. Literature Review

2.1. Systematic Literature Review

A systematic literature review is a method of synthesizing scientific evidence to answer a specific research question in a way that is transparent and reproducible while seeking to include all published evidence on a subject and assessing the quality of this evidence(Lame, 2019). By providing scientific evidence as a basis for research, it will help the research process to be more precise and quality directed

2.2. Child Stunting

Child stunting is a problem of chronic malnutrition and repeated infections in the first 1000 days of life which can failure to thrive and a risk of not having intellectual development at maximum capacity, making children more susceptible to disease and at risk of decreasing productivity levels in the future (Sutoyo, Widodo and Rochim, 2021). Stunting is defined as having a Z score of height-for-age (HAZ) underneath -2 SD that's calculated by subtracting an age- and sex-appropriate median value from a standard populace and dividing by the SD of the standard populace(Leroy and Frongillo, 2019). Stunting happens when a child does not have adequate sustenance to grow and develop, especially in the first 1000 days of life. This will be caused by destitute eat less alone but is frequently compounded by infection and poor health.

2.3. Artificial Intelligence

Artificial intelligence (AI) is defined as the new generation of technologies that are capable to interact with the environment by (i) gathering information from outside or another system; (ii) interpreting that information, recognizing patterns, deriving rules, or predicting events; (iii) generate results, answering questions, or giving instructions to other systems; and (iv) evaluating their results and improve their decision system to achieve specific objectives(Glikson and Woolley, 2020). Expert system (ES) is a branch of AI with computer-based systems that are capable to stimulate human decision making and can integrate with information systems to improve their performance and accuracy(Asemi, Ko and Nowkarizi, 2021).

3. Methodology

3.1. Research Question

The first stage for identifying problems in a study is making research questions. This is useful for facilitating research and providing boundaries to focus research. The following is a research question compiled for special research from the review as follows:

- RQ1: What keywords are in the research of artificial intelligence for diagnosing child stunting?
- RQ2: What journals have published an artificial intelligence for diagnosing child stunting?
- RQ3: What artificial intelligence algorithm is used to diagnose child stunting?
- RQ4: How many studies about diagnosing child stunting with an expert system?
- RQ5: What is the most algorithm used for diagnose?

3.2. Record Identification and Screening

3.2.1 Keywords Decision

The right keywords are needed because they are very useful and helpful in searching for previous research and studies. With proper keywords, articles that are appropriate to the research topic to be discussed can be obtained(Hardani and Kristiyanti, 2022). In this research, keywords are generated by identifying words that are in accordance with the research theme by using the AND and OR operators as needed. The following are keywords arranged for special research from research questions as follows:

- Keyword 1: *("Forward chaining" OR "backward chaining") AND ("diagnose" OR "diagnosis" OR "diagnose" OR "prevent" OR "detect" OR "prevention")*
- Keyword 2: *("machine learning" OR "expert system" OR "decision support system") AND ("stunting" OR "malnutrition") AND ("prevent" OR "prevention" OR "diagnose" OR "diagnosis" OR "screening")*
- Keyword 3: *("stunting" OR "malnutrition") AND ("expert system" OR "machine learning" OR "decision" OR "decision support system")*
- Keyword 4: *("prevent" OR "prevention" OR "preventing" OR "predict" OR "prediction" OR "diagnose" OR "diagnosis") AND ("stunting" OR "malnutrition") AND ("forward chaining" OR "fuzzy" OR "decision tree" OR "certainty factor" OR "backward chaining")*

To search for Scopus indexed articles, the keywords above are used in the Harzing's Publish or Perish (PoP) application with a search filter for only Scopus indexed articles.

3.2.2 Quality Evaluation

3.2.2.1 Inclusion and Exclusion Criteria

After the research journals are collected based on the previous keywords, all journals must be checked again for suitability with the research topic. As the main characteristics of the target population to answer the research questions, inclusion criteria and exclusion criteria were established. With inclusion criteria, it can help to focus research topics. While the exclusion criteria are useful for eliminating

factors that might interfere with the research and give inappropriate results(Patino and Ferreira, 2018). For this reason, inclusion criteria and exclusion criteria were established as follows:

Table 1. Inclusion Criteria and Exclusion Criteria

No.	Inclusion Criteria	Exclusion Criteria
1	Research journals published between 2013-2023	Research journals published before 2013
2	Research journals are in English	Research journals are not in English
3	Research journals indexed by Scopus	Research journals not indexed by Scopus
4	Research articles discussing uses of artificial intelligence including predicting or diagnose	Research articles discussing uses of artificial intelligence not including predicting or diagnose
5	Research articles that discuss AI for stunting children or the application of expert systems	Research articles that not discuss AI for stunting children or the application of expert systems

3.2.2.2 Prisma Protocol

Once inclusion criteria were decided on, the research articles continued with the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) protocol. With PRISMA there are 3 steps that must be carried out to eliminate research journals so that they are appropriate and focused on the research topic. These steps are described in the following flow diagram:

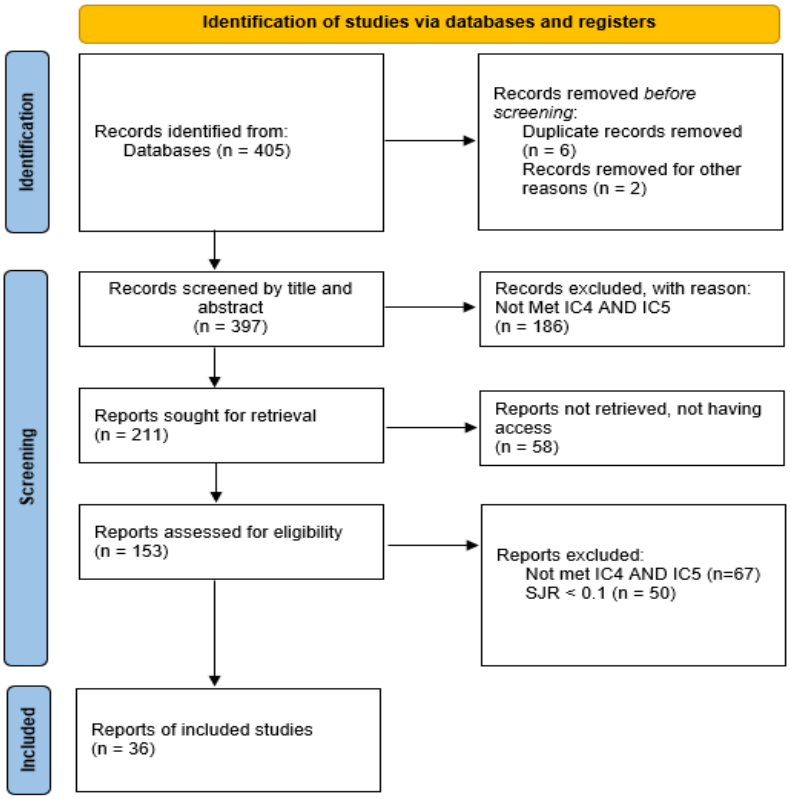

Fig.1: PRISMA flow diagram

This study reviews around 400 papers on the use of artificial intelligence to diagnose, predict, and plan nutrition for stunted children. After careful and calculated analysis, 36 papers were obtained that met the requirements according to the inclusion criteria and sufficient credibility. From the 36 papers,

information was obtained regarding the type of AI used, the algorithm method, and the research results. Out of 16 papers that focused on child stunting, it was found that 50% of the papers were using AI to predict stunting using methods such as RF, XGBoost, LR, SVM, and KNN. 44% of the papers discussed plan nutrition using the LR, Neural Network, Gradient-Boost, Bayesian Network, K-Means Clustering, Forward Chaining and Backward Chaining methods. On the other hand, there is only 1 paper that discussed the direct diagnosis of child stunting using the Certainty Factor method. Therefore, this study also reviews the use of AI for diagnosis. Using similar inclusion criteria, 20 papers were obtained regarding to the diagnosis of disease or damage with 85% of the papers using the Forward Chaining method and obtaining the smallest accuracy of 80%.

4. Result

4.1. Research Article Obtained by Keyword Search

The keywords that have been formed are used to search for research articles with the Harzing's Publish or Perish application to search for Scopus indexed research journals. The following are the search results for each keyword that has been formed;

Table 2 Number of research articles based on keywords

Keywords	Result
Keyword 1	101 articles
Keyword 2	72 articles
Keyword 3	200 articles
Keyword 4	51 articles

4.2. Research Article Based on Scopus Quartile

After obtaining research articles by searching for keywords through the Harzing's Publish or Perish application. There are 2 choices of criteria for selecting the quality of the research articles that have been obtained. Research articles will be checked using the SCImago Journal & Country Rank website. The first criterion, the journal must have an SJR value of more than 0.1 and a minimum quartile of 2. The second criterion has an SJR value of more than 0.15. Screening with the PRISMA protocol was carried out using predetermined inclusion and exclusion criteria assisted by 2 additional criteria to ensure the quality of the research articles. After screening, 36 research articles were obtained that met the qualifications with the Scopus Quartile Rating as follows;

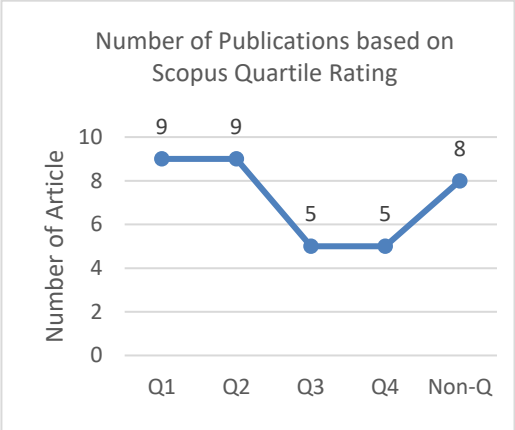

Fig.2: Graph of distribution of number of publications based on Scopus quartile rating

The following is a graph of the distribution of SJR values from research articles that meet the requirements;

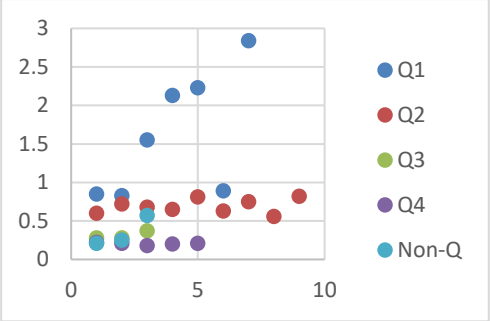

Fig. 3: Graph of distribution of SJR score

4.3. Research Article Based on Journal Publisher

Of the 36 research articles that have passed the qualifications, 29 journals publish these articles. All selected journals are indexed by Scopus and recorded on Scimago. Journal of Physics: Conference Series is the most publisher which publishes 3 qualified research articles.

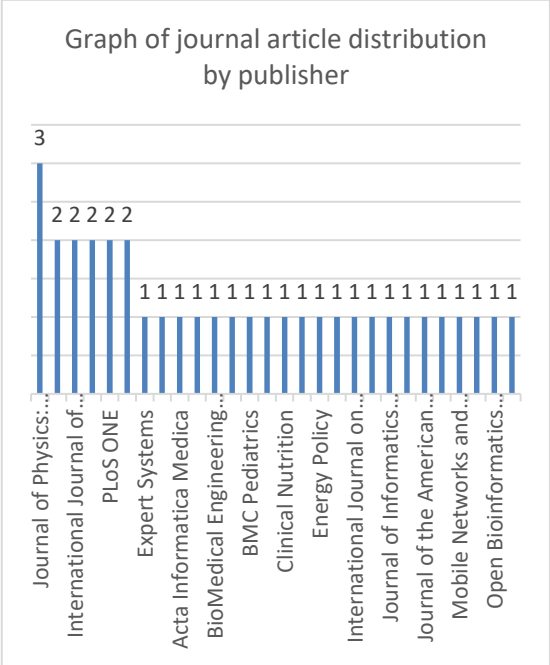

Fig.4: Graph of distribution of number of research article based on journal publisher

4.4. Research Article for Stunting or Malnutrition

16 of the 36 selected research articles discussed child stunting and/or malnutrition. The majority of research conducted is predictive with a total of 8 out of 16. The following is a graph of the distribution;

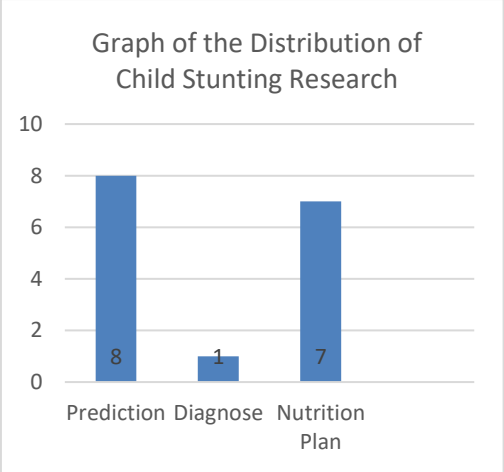

Fig.5: Graph of the distribution of child stunting research

This shows that very little research has been done to diagnose stunting in children. Where the stunting diagnosis system can help parents, who do not have the ability to pay money or remotely see a doctor to monitor their child's progress.

4.5. Algorithm for Diagnose

To diagnose stunting children, there are not many research articles discussing the diagnosis of stunting children. So, as a support, other research articles are collected to find out the expert system algorithm that can be used to make a diagnosis. The algorithms collected are algorithms from research articles that focus on diagnosing a defect or diagnosing a disease.

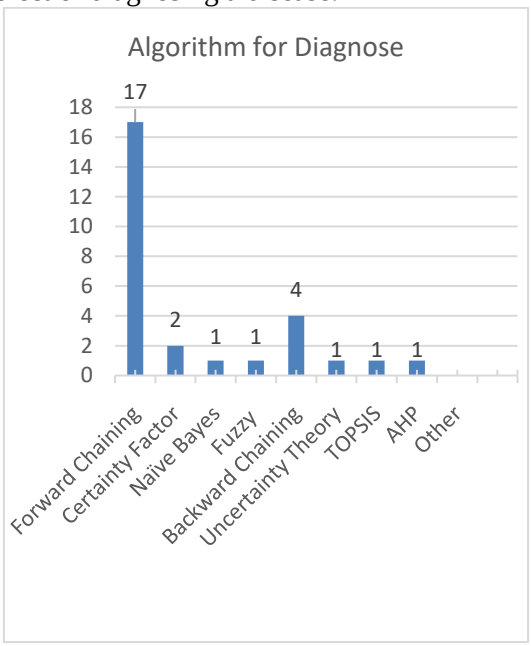

Fig. 6: Graph of algorithm for diagnosis

From the graph above, there are still many studies using the forward chaining algorithm for diagnosis.

4.6. Research Article Summary

Based on the 36 research articles included in carrying out the PRISMA protocol. The research articles have been analyzed to obtain the objectives, methods and results that have been achieved. The results of research articles are prepared in 2 categories, research articles on stunting or malnutrition and research articles on expert systems. The following table shows the results of research articles;

Table 3 Result research article about stunting or malnutrition

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Sutoyo, Widodo and Rochim, 2021)	Decision support system for handling intervention on toddlers stunting cases in Indonesia using the certainty factor method	Certainty Factor	Decision support system for stunting intervention with an accuracy value of 83%	Journal of Physics: Conference Series	2021
(Cioara *et al.*, 2018)	Expert System for Nutrition Care Process of Older Adults	Semantic Web Rule Language and SPARQL	Result by system and nutritionist is similar	Future Generations Computer Systems	2018
(NDAGIJI MANA *et al.*, 2023)	Prediction of Stunting Among Under-5 Children in Rwanda Using Machine Learning Techniques	Stratified 10-fold cross validation, Extreme gradient boosting, gradient boosting, LR, RF, SVM, naive bayes	10-fold cross validation with gradient boosting is the best with 80.49% classification and 79.33% identifying stunting	Journal of Preventive Medicine and Public Health	2023
(Harrison *et al.*, 2020)	Machine learning model demonstrates stunting at birth and systemic inflammatory biomarkers as predictors of subsequent infant growth – a four-year prospective study	Random forest	Predictors such as HAZ, AGP, CRP, and IL1 can be used as potential references	BMC Pediatrics	2020
(Rahman *et al.*, 2021)	Investigate the risk factors of stunting, wasting, and underweight among under-five Bangladeshi children and its prediction based on machine learning approach	Detection with LR, Prediction with SVM, RF and LR	The Random Forest prediction gives 88.3% for stunting, 87.7% for underweight, and 85.73% for underweight.	PLoS ONE	2021
(Bitew, Sparks and Nyarko, 2022)	Machine learning algorithms for predicting undernutrition among under-five children in Ethiopia	Extreme gradient boosting, KNN, RF, neural network and generalized linear	The XGB algorithm is superior to other ML algorithms	Public Health Nutrition	2022

Table 4 Result research article about stunting or malnutrition (continued)

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Talukder and Ahammed, 2020)	Machine learning algorithms for predicting malnutrition among under-five children in Bangladesh	LDA, K-NN, SVM, Random Forest, Logistic Regression	Random Forest Method give accuracy 68.5%, sensitive 94.66% and specify 69.76%	Nutrition	2020
(Fenta, Zewotir and Muluneh, 2021)	A machine learning classifier approach for identifying the determinants of under-five child undernutrition in Ethiopian administrative zones	LR, Least Absolute Shrinkage and Selection Operator (L1), L-2 regularization (Ridge), Elastic net, Neural network, RF	Random Forest with 68.2% accuracy and 76.2%AUC	BMC Medical Informatics and Decision Making	2021
(Gusman and Hendri, 2019)	Expert system to diagnose child development growth disorders with forward chaining method	Forward Chaining	Expert system for diagnosing diseases in children's growth and development and information on how parents behave and treat their children	Journal of Physics: Conference Series	2019
(Cruz *et al.*, 2014)	A Validation of an Intelligent Decision-Making Support System for the Nutrition Diagnosis of Bariatric Surgery Patients	Bayesian Network	The results given are in accordance with 4 experts with a rating of 80% -93% depending on the nutritional diagnosis and 100% with the Gold Standard	JMIR Medical Informatics	2014
(Yin *et al.*, 2021)	A fusion decision system to identify and grade malnutrition in cancer patients: Machine learning reveals feasible workflow from representative real-world data	K-Means clustering	well-nourished cluster (n=8193, 58%), malnourished cluster with 3 phenotype severity levels (mild = 2195, 15.5%; moderate = 2491, 17.6%; severe = 1255, 8.9%)	Clinical Nutrition	2021

Table 5 Result research article about stunting or malnutrition (continued)

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Timsina *et al.*, 2020)	MUST-Plus: A Machine Learning Classifier That Improves Malnutrition Screening in Acute Care Facilities	MUST-Plus	MUST-Plus provides higher sensitivity, specification and increase AUC than classic MUST	Journal of the American College of Nutrition	2020
(Chilyabanyama *et al.*, 2022)	Performance of Machine Learning Classifiers in Classifying Stunting among Under-Five Children in Zambia	Logistic Regression, Random Forest, SV classification, XG Boost, Naive Bayes	RF is the most accurate algorithm with 79% on testing and 61.6% on training	Children	2022
(Jin *et al.*, 2022)	Predicting malnutrition from longitudinal patient trajectories with deep learning	Neural Networks, gradient-boost tree, logistic regression	Produce a reliable system that produces better performance with less data required than existing instruments	PLoS ONE	2022
(Anggraini, Rochimah and Dalmi, 2014)	Mobile nutrition recommendation system for 0–2-year infant	Backward chaining, forward chaining	The system is accepted 79.5% with the use as a nutritional recommendation of 87%	2014 ICCIS-Proceedings	2014
(Rochimah, Sianipar and Anggraini, 2016)	Mobile application for guidance and provision of toddler's nutrition to support e-PKK	Backward chaining, forward chaining	A successful system was built that has information content regarding nutrition, growth and disease management for infants aged 0-2 years	IOP Conference Series: Materials Science and Engineering	2016

Table 6 Result research article about expert system

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Munaiseche, Kaparang and Rompas, 2018)	An Expert System for Diagnosing Eye Diseases using Forward Chaining Method	Forward chaining	An expert system with high usability and learnability values	IOP Conference Series: Materials Science and Engineering	2018
(Muludi *et al.*, 2018)	Implementation of Forward Chaining and Certainty Factor Method on Android-Based Expert System of Tomato Diseases Identification	Forward chaining and certainty factor	correct solution value of 76.11% from 44 test	International Journal of Advanced Computer Science and Applications	2018
(Hayadi *et al.*, 2017)	Expert System of Quail Disease Diagnosis Using Forward Chaining Method	Forward chaining	Provide appropriate results from the diagnosis based on Rules	Indonesian Journal of Electrical Engineering and Computer Science	2017
(Urwyler *et al.*, 2015)	Recognition of activities of daily living in healthy subjects using two ad-hoc classifiers	Rule based forward chaining inference engine and circadian activity rhythm	Both AD-hoc classifier methods provide better performance than the state-of-art classifier	BioMedical Engineering Online	2015
(Hafizal *et al.*, 2023)	Implementation of expert systems in potassium deficiency in cocoa plants using forward chaining method	Forward chaining	Expert system with 88% accuracy from 100 trials	Procedia Computer Science	2023

Table 7 Result research article about expert system (continued)

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Fiarni *et al.*, 2015)	Automated Scheduling System for Thesis and Project Presentation Using Forward Chaining Method with Dynamic	Forward chaining with dynamic allocation resource	100% results equal to those made by experts	Procedia Computer Science	2015

	Allocation Resources				
(Govindan, Mina and Alavi, 2020)	A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19)	Fuzzy inference System	SPK to determine the handling of Covid-19 by following the logical patterns and confirmed performance	Transportation Research Part E: Logistics and Transportation Review	2020
(Zhang *et al.*, 2018)	Evaluation of the benefits of using a backward chaining decision support expert system for local flood forecasting and warning	Backward chaining	The Backward chaining method satisfies flood experts more than the Forward Chaining method	Expert Systems	2018
(Anggrawan *et al.*, 2021)	Machine Learning for Diagnosing Drug Users and Types of Drugs Used	Forward Chaining and Certainty Factor	80% accuracy	International Journal of Advanced Computer Science and Applications	2021
(Saiful and Muliawan Nur, 2020)	Application of Expert System with Web-Based Forward Chaining Method in Diagnosing Corn Plant Disease	Forward Chaining	The system can be used to assist farmers in diagnosing and providing solutions to corn diseases	Journal of Physics: Conference Series	2020

Table 8 Result research article about expert system (continued)

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Dashti and Dashti, 2020)	An expert system to diagnose spinal disorders	Backward Chaining inference and Uncertainty Theory	The resulting results are similar to the results of 4 experts	Open Bioinformatics Journal	2020
(Sajid and Hussain, 2018)	Rule Based (Forward Chaining/Data Driven) Expert System for Node Level Congestion Handling in Opportunistic Network	Forward Chaining	Provides better performance than MaxProp protocol	Mobile Networks and Applications	2018

(Sivaram *et al.*, 2019)	Expert System in Determining the Quality of Superior Gourami Seed Using Forward Chaining-Based Websites	Forward Chaining	Obtain gourami seeds that meet the specified criteria	Communication in Computer and Information Science	2019
(Othman, Arbaiy and Rahman, 2018)	An Expert System for Pneumococcal Prognosis	Forward Chaining	An expert system for diagnosing pneumococci that can be used to obtain information about the disease and perform self-checking to help prevent the disease.	International Journal on Informatics Visualization	2018
(Konstantinos, Georgios and Garyfalos, 2019)	A Decision Support System methodology for selecting wind farm installation locations using AHP and TOPSIS: Case study in Eastern Macedonia and Thrace region, Greece	AHP & TOPSIS	Generates a DSSM that can determine the exact location for the Wind Farm installation	Energy Policy	2019

Table 9 Result research article about expert system

Reference	*Title*	*Method*	*Result*	*Journal*	*Year*
(Naryanto *et al.*, 2022)	Development of a mobile expert system for the diagnosis on motorcycle damage using forward chaining algorithm	Forward Chaining	Producing a system that works 100% with 100% accuracy when diagnosing damage to motorcycles	Indonesian Journal of Electrical Engineering and Computer Science	2022
(Rumapea and Yohanna, 2019)	Expert System for Using Ulos Types on Traditional Batak Events with the Web-Based Forward Chaining Method	Forward Chaining	The results of the recommendations are in accordance with the results of the consultation	Journal of Informatics Telecommunication Engineering	2019
(Tachpetpaiboon, Kularbphettong and Janpla, 2019)	Expert System for Diagnosing Disease Risk from Urine Tests	Forward Chaining, Naive Bayes, C4.5	The results of Forward chaining inference and C4.5 give better Recall, Precision and F-measure values	Advances in Intelligent Systems and Computing	2019

(Jeddi, Arabfard and Kermany, 2017)	Intelligent Diagnostic Assistant for Complicated Skin Diseases through C5's Algorithm	C5, forward chaining inference	99.56% accuracy and 0.44% error during training, 98% accuracy and 2% error during test	Acta Informatica Medica	2017
(Hatta *et al.*, 2017)	Web-expert system for the detection of early symptoms of the disorder of pregnancy using a forward chaining and Bayesian method	Forward Chaining, Bayesian	system suitability value of 97% and accuracy of 82.86%.	Journal of Theoretical and Applied Information Technology	2017

Nutrition data are high-dimensional and complex, so that AI especially ML make it suitable for analysis. ML can deal with nutrition problems, such as obesity, metabolic health and malnutrition. The limitation of this study, most of these systems perform poorly as the intelligence has yet to be achieved when it is not applied appropriately because it can lead to biased models that do not represent real representative. Accuracy and effectiveness of AI-based stunting diagnosis systems can be achieved by providing labels on a subset of data and evaluating performance due to broad task, type and model. Potential ethical consideration associated with AI-based stunting diagnosis systems is concerned to minimize the ethical harms from AI in society, such as poor unethical design, inappropriate application or misuse (Kirk *et al.*, 2022).

5. Conclusion

This research reviews research journals that discuss child stunting and malnutrition as well as the use of artificial intelligence as a diagnostic system with the aim of knowing what research can be done to help parents monitor children's development so they can avoid stunting. Based on the results of a systematic review using the PRISMA protocol, it is known that the use of Artificial Intelligence for stunting is more widely used as a prediction system with very few diagnostic systems, therefore research to build a child stunting diagnostic system can be explored further. For starters, the forward chaining method has been chosen by many researchers to conduct research that creates diagnostic systems.

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