Diagnostic Performance of the StrongKids Tool for Identifying Hospital-Acquired Malnutrition in Pediatric Inpatients

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Abstract: *Background:* Hospital-acquired malnutrition is a critical yet often underrecognized condition in pediatric inpatients and is associated with adverse clinical outcomes, including prolonged hospitalization and increased morbidity. Reliable screening tools such as STRONGkids are essential to facilitate early identification, but their diagnostic performance may vary across settings.

Methods: This diagnostic accuracy study with prospective in-hospital follow-up was conducted among pediatric inpatients aged 1 month to 18 years in Wangaya Regional General Hospital, Denpasar, from September to November 2025. STRONGkids screening was performed within 24 hours of admission. Hospital-acquired malnutrition was determined based on percentage body weight loss measured at admission and discharge. Diagnostic performance was assessed using sensitivity, specificity, predictive values, likelihood ratios, and ROC curve analysis, with optimal cut-off determined by the Youden Index.

Results: Among 92 pediatric inpatients, hospital-acquired malnutrition occurred in 34.7%. No significant associations were observed between malnutrition and sex, age, baseline nutritional status, diagnosis, disease category, or length of hospital stay (all $p > 0.05$), although baseline nutritional status showed a near-significant trend ($p = 0.072$). Receiver operating characteristic analysis demonstrated moderate discriminative ability of STRONGkids (AUC = 0.676). A cut-off score of ≥1 yielded the highest Youden Index (0.558), with a sensitivity of 87.5%, specificity of 68.3%, positive predictive value of 59.6%, and negative predictive value of 91.1%.

Conclusion: STRONGkids is a valuable screening tool for early detection of hospital-acquired malnutrition in pediatric inpatients, supporting routine universal nutritional screening.

Keyword: Pediatric malnutrition, hospital-acquired malnutrition, STRONGkids, nutritional screening, diagnostic accuracy, ROC analysis, weight loss, pediatric inpatients.

INTRODUCTION

Hospital-acquired malnutrition refers to a decline in a patient's nutritional status that develops during hospitalization, regardless of their nutritional condition upon admission. It represents a primary clinical and public health concern in pediatric populations. Prior studies have reported considerable variability in its prevalence, ranging from 10.2% to 34.9%, depending on the healthcare setting, population characteristics, and diagnostic criteria applied [1-5]. An extensive multicenter study conducted across 12 European countries documented weight loss in 23% of hospitalized children who remained in care for more than four days [6]. Similarly, Sidiartha *et al.* observed a prevalence of 30% at Sanglah General Hospital [7], while substantially lower rates were reported in Dr. Sardjito General Hospital (10.7%) and Hasan Sadikin Hospital (9%) [8, 9] These discrepancies likely reflect methodological heterogeneity, variation in screening and assessment practices, and the absence of a universally accepted definition of pediatric malnutrition [10].

Hospital-acquired malnutrition is associated with markedly adverse outcomes, including prolonged hospitalization, delayed recovery, increased susceptibility to infections, higher risk of complications, and elevated mortality and healthcare costs [11]. In clinical practice, malnutrition in hospitalized children often remains undetected when assessments rely solely on anthropometric indicators or routine clinical evaluation. Consequently, validated and sensitive nutritional screening tools are essential to facilitate early identification and timely intervention.

Several pediatric nutritional screening tools have been developed, including the Pediatric Yorkhill Malnutrition Score (PYMS), the Screening Tool for the Assessment of Malnutrition in Pediatrics (STAMP), and the Screening Tool for Risk on Nutritional Status and Growth (STRONGkids). Evidence from comparative studies, including studies from Moeeni *et al.* demonstrates that STRONGkids performs with higher reliability and greater clinical usefulness to identify children at nutritional risk than many other available tools [12].

Consistent findings have been reported in Indonesian and international settings. Sidiartha *et al.* confirmed that STRONGkids effectively identifies

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children at risk of hospital-acquired malnutrition across multiple government hospitals [13]. At the same time, Tommy *et al.* demonstrated high sensitivity in detecting at-risk pediatric patients in Aceh [14]. Maciel *et al.* likewise reported high diagnostic sensitivity, supporting its suitability for early risk identification [15]. Although evidence supports STRONGkids as a promising predictive tool, its diagnostic performance remains context-dependent and may vary across populations and hospital environments.

Wangaya Regional General Hospital has adopted STRONGkids as its routine malnutrition screening instrument due to its practicality and ease of use by nurses and dietitians. Developed by Hulst *et al.*, STRONGkids assesses four domains-subjective clinical impression, presence of high-risk disease, nutritional intake and losses, and recent weight loss or inadequate weight gain-yielding a total score between 0 and 5 [16]. Patients are stratified into low (0), moderate (1-3), or high (4-5) nutritional risk categories.

Given the persistent burden and potential clinical consequences of hospital-acquired malnutrition, this study was designed to evaluate the diagnostic effectiveness of STRONGkids in identifying malnutrition among pediatric inpatients at Wangaya Regional General Hospital.

MATERIAL AND METHODS

Study Design

This study employed an analytical observational diagnostic accuracy design with prospective in-hospital follow-up. STRONGkids screening and baseline characteristics were assessed cross-sectionally at admission. In contrast, body weight was measured prospectively at two predefined time points: upon hospital admission and immediately before discharge on the day the patient was released from inpatient care, within the same hospitalization episode for all enrolled participants.

Although no post-discharge follow-up was performed, the repeated in-hospital weight measurements constitute a short-term prospective component required to ascertain hospital-acquired malnutrition.

Study Setting and Period

The study was conducted in the Kaswari Ward of Wangaya Regional General Hospital, Denpasar, Bali, Indonesia, from September to November 2025.

Participants

Participants and Flow of Subjects

All pediatric inpatients admitted during the study period were screened using sequential (consecutive) sampling.

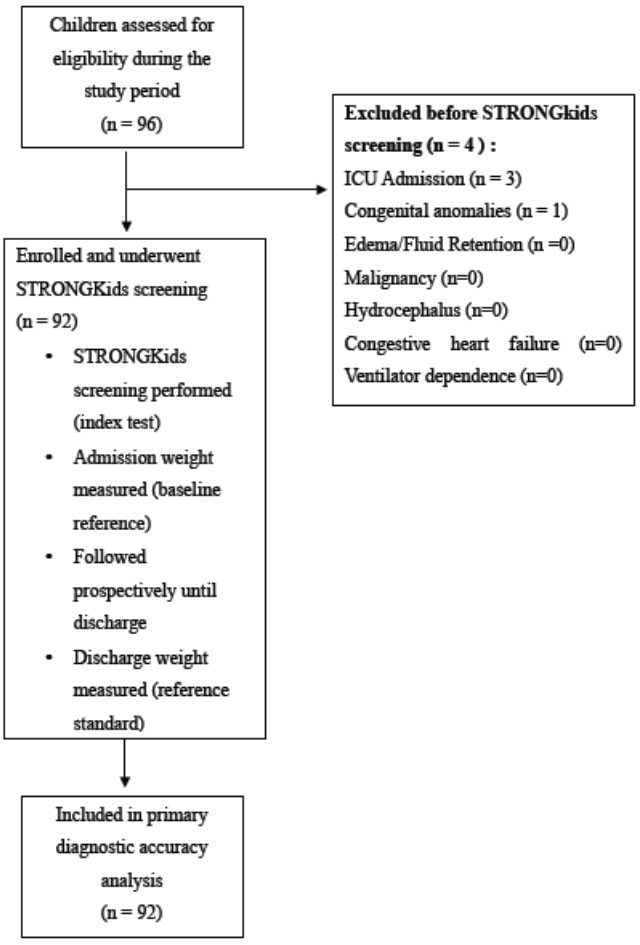


Figure 1: STARD flow diagram illustrating participant eligibility assessment, exclusion, enrollment, prospective follow-up, and inclusion in the diagnostic accuracy analysis.

All enrolled children underwent STRONGkids screening at admission and were prospectively followed until discharge for assessment of hospital-acquired malnutrition based on percentage weight loss.

Inclusion Criteria

Children aged 1 month to 18 years whose parents or legal guardians provided written informed consent.

Exclusion criteria

Children were excluded if they had:

- Conditions associated with fluid retention (edema, nephrotic syndrome, congestive heart failure),
- Malignancy,

- Hydrocephalus or significant congenital anomalies,
- Admission to intensive care units,
- Mechanical ventilation,
- Terminal illness,
- Death on arrival.

Participant flow is illustrated in Figure **1**.

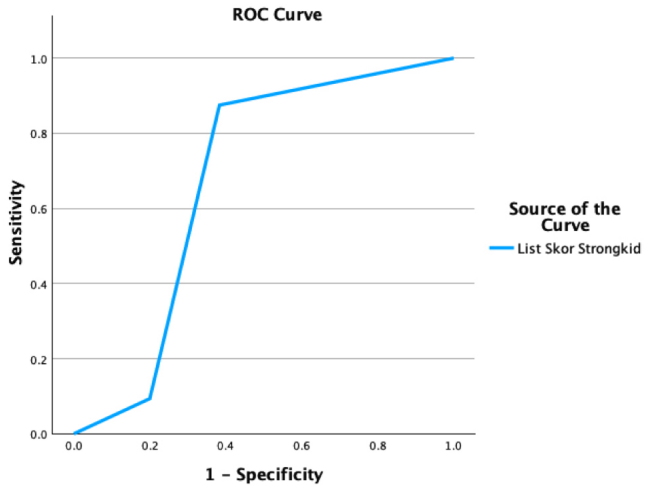


Figure 2: ROC Curve of STRONGkids for Hospital-Acquired Malnutrition.

Sample Size Determination

The minimum sample size was calculated using a diagnostic accuracy formula for sensitivity:

The resulting minimum sample size was 92 participants.

n = 92

Where:

- Zα = standard deviation alpha, type I error is set at 5%, so Zα = 1.96
- Expected sensitivity (Se) = 0.80
- Estimated prevalence of hospital-acquired malnutrition (Prev) = 0.30
- Desired precision (d) = 0.15
- Confidence level = 95% (Z = 1.96)

Data Collection Procedures

Strong kids Screening

Strong kids assessment was conducted within the first 24 hours of admission through structured interviews with parents or caregivers and review of medical records. The tool evaluates four domains: subjective clinical assessment, presence of high-risk disease, nutritional intake and losses, and recent weight loss or inadequate weight gain.

Strong kids scores range from 0 to 5, with higher scores indicating greater nutritional risk. For analytical purposes, Strong kids scores were dichotomized into two categories: 0 = not at risk; ≥1 = at nutritional risk, in accordance with the ROC-derived optimal cut-off used in this study.

Body Weight Measurement (Reference Standard)

Baseline (admission) body weight was measured directly in the hospital and not recalled in all participants.

- Children weighing <10 kg were measured using a calibrated digital infant scale (OneMed®) in the supine position.
- Children weighing ≥10 kg were measured using a calibrated digital standing scale.

Weight measurements were:

- Performed by trained nursing staff,
- Using the same scale for each child at admission and discharge,
- Conducted with minimal clothing; diapers were removed before measurement.
- Scales were calibrated routinely according to hospital protocol.

Body weight was measured twice only:

1. At admission,
2. At discharge.

No intermediate measurements were used for outcome classification.

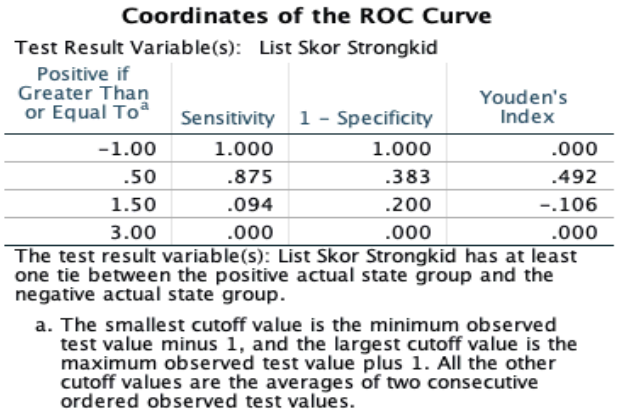
Definition of Hospital-Acquired Malnutrition

Hospital-acquired malnutrition was defined based on percentage weight loss during hospitalization, calculated as [14]:

$$\frac{Admission\ weight - Discharge\ weight}{Admission\ weight} \times 100\%$$

Malnutrition was classified as:

- 2% weight loss within ≤7 days,
- 5% weight loss within 8-30 days,
- 10% weight loss after >30 days of hospitalization.



Coordinates of the ROC Curve

Test Result Variable(s): List Skor Strongkid

Positive if Greater Than or Equal To[a]	Sensitivity	1 – Specificity	Youden's Index
-1.00	1.000	1.000	.000
.50	.875	.383	.492
1.50	.094	.200	-.106
3.00	.000	.000	.000

The test result variable(s): List Skor Strongkid has at least one tie between the positive actual state group and the negative actual state group.

a. The smallest cutoff value is the minimum observed test value minus 1, and the largest cutoff value is the maximum observed test value plus 1. All the other cutoff values are the averages of two consecutive ordered observed test values.

Figure 3: Coordinates of the ROC Curve.

Table 1: Association between Baseline Characteristics and Hospital-Acquired Malnutrition (n = 92)

Variable	Hospital acquired Malnutrition Yes n (%)	Hospital acquired Malnutrition No n (%)	Total n (%)	p-value
Gender				
Male	23 (38.3)	37 (39.1)	60 (100)	0.328
Female	9 (28.1)	23 (71.9)	32 (100)	
Age				
< 2 years old	5 (25.0)	15 (75.0)	20 (100)	0.508
2-10 years old	19 (39.6)	29 (60.4)	48 (100)	
> 10 years old	8 (33.3)	16 (66.7)	24 (100)	
Initial Nutritional Status				
Well nourished	29 (39.2)	45 (60.8)	74 (100)	0.072
Malnourished	3 (16.7)	15 (83.3)	18 (100)	
Diagnose				
Single	6 (46.2)	7 (53.8)	13 (100)	0.353
Multiple	26 (32.9)	53 (67.1)	79 (100)	
Disease Category				
Gastroenterohepatology	15 (35.7)	27 (64.3)	42 (100)	0.586
Neuropediatric	2 (28.6)	5 (71.4)	7 (100)	
Pulmonology	5 (35.7)	9 (64.3)	14 (100)	
Tropical Infectious and Disease	15 (68.2)	7 (31.8)	22 (100)	
Nutritional & Metabolic Disease	0 (0)	0 (0)	0	
Cardiology	0 (0)	0 (0)	0	
Nephrology	2 (100.0)	0 (0)	2 (100)	
Hemato-oncology	0 (0)	0 (0)	0	
Allergy-immunology	1 (25.0)	3 (75.0)	4 (100)	
Endocirne	0 (0)	1 (100.0)	1 (100)	
The length of stay				
2-4 days	16 (32.0)	34 (68.0)	50 (100)	0.541
≥5 days	16 (38.1)	26 (61.9)	42 (100)	

Table 2: Relationship between Strong Kids Score and Hospital-Acquired Malnutrition

STRONG Kids	Hospital Acquired Malnutriton Yes n (%)	Hospital Acquired Malnutrition No n (%)	Total	P value
At Risk (score ≥1) n (%)	28 (59.6)	19 (40.4)	47 (100)	< 0.001
No Risk (score 0) n (%)	4 (8.9)	41 (91.1)	45 (100)	

Table 3: Area under the ROC Curve for STRONGkids in Predicting Hospital-Acquired Malnutrition

Area Under ROC curve	Std. Error	Asymptotic Sig. b	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.676	0.057	0.002	0.565	0.788

Study Variables

- Index test: Strong kids score (dichotomized into two categories: a score of 0 classified as not at risk, and a score of ≥1 classified as at nutritional risk).
- Reference standard: Hospital-acquired malnutrition (yes/no).
- Covariates: sex, age, baseline nutritional status, primary diagnosis, disease category, and length of hospital stay.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 31.0.

- Categorical variables were summarized as frequencies and percentages.
- Associations were tested using Chi-square tests; Fisher's exact test was applied when expected cell counts were <5.
- No missing outcome data were observed, as all enrolled patients were followed until discharge.

Outcome Measures

The primary outcome was the diagnostic accuracy of the STRONGkids tool. Secondary outcomes included associations between patient characteristics and hospital-acquired malnutrition.

Diagnostic Accuracy Analysis

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), favorable likelihood ratio (LR+), and negative likelihood ratio (LR-) were calculated with 95% confidence intervals.

Receiver Operating Characteristic (ROC) analysis was performed, and the optimal STRONGkids cut-off was determined using the highest Youden Index.

Because STRONGkids is an integer-based scoring system, the ROC-derived cut-off value of ≥0.5 was operationally interpreted as STRONGkids ≥1 for clinical and analytical purposes.

Consideration of Confounding Factors

Only bivariate analyses were performed. Potential confounders such as disease severity, fasting or nil per os periods, enteral feeding, and intravenous fluid administration were not systematically measured and therefore not adjusted for in multivariable models. These factors are acknowledged as unmeasured confounders.

Ethical Considerations

Ethical approval for this study was obtained from the Ethics Committee of Wangaya Regional General Hospital, Denpasar, Bali, Indonesia, with approval number No. 000.9.2/5546/RSUDW. Written informed consent was obtained from the parents or legal guardians of all participating children before enrollment.

RESULT

Among the 92 enrolled participants, no statistically significant associations were identified between most baseline patient characteristics and hospital-acquired malnutrition. The proportion of malnutrition was comparable between males (38.3%) and females (28.1%), with no significant difference observed (p =

0.328). Similarly, malnutrition rates across age groups-25.0% in children younger than 2 years, 39.6% in those aged 2-10 years, and 33.3% in children older than 10 years-did not differ significantly (p = 0.508).

Children who were well nourished at admission had a higher proportion of hospital-acquired malnutrition (39.2%) than those who were malnourished at admission (16.7%). Although this association did not reach statistical significance (p = 0.072), it suggested a possible trend indicating that baseline nutritional status at admission may influence the risk of developing hospital-acquired malnutrition.

No significant associations were observed between hospital-acquired malnutrition and the type of initial diagnosis (single versus multiple diagnoses; p = 0.353). When stratified by disease category, children with infectious and tropical diseases exhibited the highest proportion of malnutrition (68.2%), followed by those with gastrointestinal diseases (35.7%); however, these differences were not statistically significant (p = 0.586). Hospital-acquired malnutrition was observed in 1 child (25.0%) in the allergy-immunology category, whereas none occurred in the cardiology, nephrology, hematology-oncology, or endocrinology categories.

Length of hospital stay was not significantly associated with hospital-acquired malnutrition (p = 0.541), although a higher proportion was observed among children hospitalized for ≥5 days (38.1%) compared with those hospitalized for ≤4 days (32.0%). Overall, these findings indicate that baseline demographic and clinical characteristics were not significantly associated with hospital-acquired malnutrition in this cohort. However, no significant trends were observed in baseline nutritional status or hospitalization duration.

Receiver operating characteristic (ROC) curve analysis demonstrated that the STRONGkids score had moderate discriminative ability for predicting hospital-acquired malnutrition, with an area under the curve (AUC) of 0.676. Based on ROC coordinates, the optimal threshold was identified at a STRONGkids score of ≥1, yielding the highest Youden Index (0.558) and providing the most favorable balance between sensitivity (87.5%) and specificity (68.3%). These results indicate that the STRONGkids tool demonstrates meaningful predictive performance at scores ≥1, supporting its use as a screening instrument to identify hospitalized children at increased risk of developing hospital-acquired malnutrition.

DISCUSSION

The present study found no statistically significant associations between baseline demographic or clinical characteristics and the development of hospital-acquired malnutrition among pediatric inpatients. Sex and age distributions showed no meaningful differences, consistent with previous studies suggesting that these variables exert limited influence on short-term nutritional deterioration during hospitalization [16, 17]. Although not statistically significant, children aged 2-10 years exhibited the highest proportion of hospital-acquired malnutrition, indicating that school-aged children may be more susceptible to reduced intake during acute illness compared with infants and adolescents.

A noteworthy finding was the near-significant trend observed for baseline nutritional status at admission (p = 0.072). Children who were well nourished at admission experienced a higher proportion of hospital-acquired malnutrition than those who were already malnourished. This seemingly paradoxical finding has been reported in previous studies. It may be explained by closer monitoring and earlier nutritional intervention among children identified as malnourished at admission. In contrast, well-nourished children may receive less intensive nutritional attention until clinically evident weight loss occurs [15, 18]. These findings highlight the importance of universal nutrition screening regardless of baseline nutritional status.

Disease categories were not significantly associated with hospital-acquired malnutrition; however, children with infectious and tropical diseases exhibited the highest proportions. This observation aligns with established physiological mechanisms, as infection increases metabolic demands, triggers inflammatory responses, and suppresses appetite, all of which contribute to nutritional decline [19, 20]. Higher proportions were also observed among children with gastrointestinal diseases, likely related to impaired nutrient absorption, vomiting, or diarrhea, as described in previous literature [21]. No cases of hospital-acquired malnutrition were identified in several subspecialty categories, including cardiology, nephrology, hematology-oncology, and endocrinology; however, interpretation is limited by the small number of cases in these groups.

The length of hospital stay showed a nonsignificant trend toward higher malnutrition rates among children hospitalized for ≥5 days. This finding is consistent with earlier studies indicating that cumulative metabolic

stress, repeated fasting for procedures, and reduced oral intake during prolonged hospitalization contribute to nutritional deterioration [22]. Collectively, these findings reinforce the multifactorial nature of hospital-acquired malnutrition, which may occur independently of baseline demographic or clinical characteristics.

The proportion of hospital-acquired malnutrition observed in this study was 34.7%. This estimate is comparable to findings from previous studies conducted in Indonesia. A retrospective cohort study by Sidiartha *et al.* at Sanglah General Hospital, Denpasar, reported an incidence of 30.1% among hospitalized children aged 5 years or younger [7]. Similarly, Tommy *et al.* reported a prevalence of 29.3% in a cross-sectional study conducted at Zainoel Abidin General Hospital in Banda Aceh [14]. In contrast, a prospective cohort study by Sugiharto *et al.* reported a lower prevalence of 15.4% among pediatric inpatients [22].

Variations in prevalence across studies likely reflect differences in study design, population characteristics, age range, and nutritional assessment methods. Prospective cohort studies allow for more precise monitoring of nutritional changes, whereas retrospective and cross-sectional designs rely on secondary data and may be affected by inconsistencies in documentation. Differences in hospital characteristics may also contribute to variability, as type B hospitals and tertiary referral centers differ in staffing, nutrition support resources, institutional policies, and case complexity.

Definitions of hospital-acquired malnutrition also varied across studies. Sidiartha *et al.* defined malnutrition based on changes in weight-for-height Z-scores, using a 0.5 SD threshold [13], whereas Sugiharto *et al.* applied a criterion of >2% weight loss during hospitalization [22]. Both the present study and Tommy *et al.* used definitions incorporating >2% weight loss for short hospital stays, ≥5% for stays of 8-30 days, and ≥10% for prolonged hospitalization [14]. Such heterogeneity in diagnostic criteria contributes to differences in reported prevalence.

A highly significant association was observed between STRONGkids risk categories and hospital-acquired malnutrition ($p < 0.001$). Using a cut-off score of ≥1, STRONGkids demonstrated high sensitivity (87.5%), moderate specificity (68.3%), and positive and negative predictive values of 59.6% and 91.1%, respectively, indicating good performance in identifying children at risk of nutritional deterioration during hospitalization.

These findings are consistent with previous studies validating STRONGkids in various clinical settings. Tommy *et al.* reported a sensitivity of 77.3% and specificity of 54.7%, with a significant association between STRONGkids scores and malnutrition risk [14]. Huysentruyt *et al.* reported a sensitivity of 71.9% and a high negative predictive value of 94.8%, supporting the tool's utility for excluding low-risk patients [23]. Similarly, Spagnuolo *et al.* demonstrated a significant association between STRONGkids scores and hospital-acquired malnutrition, albeit with moderate specificity [24].

Conversely, variability in performance has been reported across populations. Semsawat *et al.* observed lower sensitivity and specificity in a tertiary care setting, underscoring the influence of local disease burden and nutritional epidemiology on screening tool performance [25]. Carter *et al.* compared STRONGkids with the Pediatric Nutrition Screening Tool and demonstrated improved diagnostic accuracy after recalibrating cut-off points using ROC analysis, suggesting that optimization may enhance screening performance [18].

In the present study, ROC analysis demonstrated that STRONGkids had moderate discriminatory ability, with an AUC of 0.676. The optimal cut-off identified using the Youden Index (0.558) was ≥ 1, yielding high sensitivity and acceptable specificity. This finding suggests that the risk of hospital-acquired malnutrition increases beginning at a STRONGkids score of 1 in this population.

Compared with previous local studies, the present study provides a more methodologically robust evaluation by incorporating ROC-based cut-off optimization. Earlier studies primarily relied on predefined STRONGkids risk categories without recalibration, potentially limiting diagnostic accuracy [13, 14]. By contrast, the present study represents one of the first local efforts to derive a data-driven STRONGkids cut-off using ROC analysis.

International studies have similarly reported variability in optimal STRONGkids thresholds. Carter *et al.* proposed revised risk categories following recalibration [18], while studies from Brazil conducted by Castro et al suggested higher thresholds (≥ 3) based on association with clinical outcomes [26]. These differences highlight that STRONGkids performance is context-dependent and influenced by local malnutrition prevalence, patient characteristics, and disease profiles.

By identifying a cut-off of ≥1, the present study supports the use of a highly sensitive threshold for early nutritional risk detection in this clinical setting. High sensitivity is significant in screening contexts to minimize missed cases and facilitate timely nutritional intervention. This approach may help hospitals refine nutrition screening protocols, improve early identification, and strengthen multidisciplinary nutritional care during hospitalization.

Although ROC analysis identified a STRONGkids cut-off score of ≥1 as the statistically optimal threshold based on the highest Youden Index, its clinical implications should be interpreted cautiously. This lower cut-off prioritizes sensitivity and facilitates early identification of children at risk of hospital-acquired malnutrition, but may increase the number of patients classified as at risk and the associated clinical workload.

As STRONGkids is intended for initial risk stratification rather than definitive diagnosis, potential over-identification at the screening stage may be acceptable to support early nutritional assessment, monitoring, and preventive intervention. Children identified as at risk do not necessarily require intensive nutritional therapy; they should, however, undergo closer observation and follow-up assessment. Therefore, implementation of a ≥1 cut-off should be integrated within a stepwise clinical pathway and adapted to local resource availability to balance sensitivity with operational feasibility.

CONCLUSION

STRONGkids demonstrated good diagnostic performance in identifying hospital-acquired malnutrition among pediatric inpatients at Wangaya Regional General Hospital, with high sensitivity (87.5%), moderate specificity (68.3%), moderate positive predictive value (59.5%), and high negative predictive value (91.1%). Receiver operating characteristic (ROC) curve analysis further indicated a moderate discriminative ability, with an area under the curve (AUC) of 0.676. The optimal cut-off point, determined by the highest Youden Index, corresponded to a STRONGkids score of ≥1, indicating that the risk of developing hospital-acquired malnutrition begins to increase from this threshold.

No statistically significant associations were observed between hospital-acquired malnutrition and baseline patient characteristics, including sex, age, nutritional status at admission, primary diagnosis, disease category, and length of hospital stay. These findings suggest that the risk of nutritional deterioration during hospitalization is not confined to specific demographic or clinical subgroups, thereby reinforcing the importance of universal nutritional screening at admission.

Overall, STRONGkids is an effective and practical screening tool for identifying pediatric inpatients at risk of hospital-acquired malnutrition. Its high sensitivity and substantial negative predictive value support its role in routine clinical practice, facilitating timely nutritional assessment and targeted intervention. At the same time, its implementation should be integrated within a structured clinical pathway to optimize resource utilization.

LIMITATIONS

This study has several limitations. It was conducted at a single center with a relatively short study period, which may limit generalizability. Although standardized procedures were applied, measurement error in body weight cannot be entirely excluded. Nutritional interventions during hospitalization were not controlled, and blinding was not applied. The absence of body composition or dietary intake assessment may have led to misclassification. Finally, external validity may be limited, and multicenter studies are warranted.

SUPPLEMENTARY TABLE

The supplementary table can be downloaded from the journal website along with the article.

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