GTFCC Case Management Working Group Meeting

Evaluation of Dehydration in Children and Adults

Adam C. Levine, MD, MPH, FACEP
Professor of Emergency Medicine and Health Services, Policy & Practice
Director, Center for Human Rights and Humanitarian Studies
Brown University

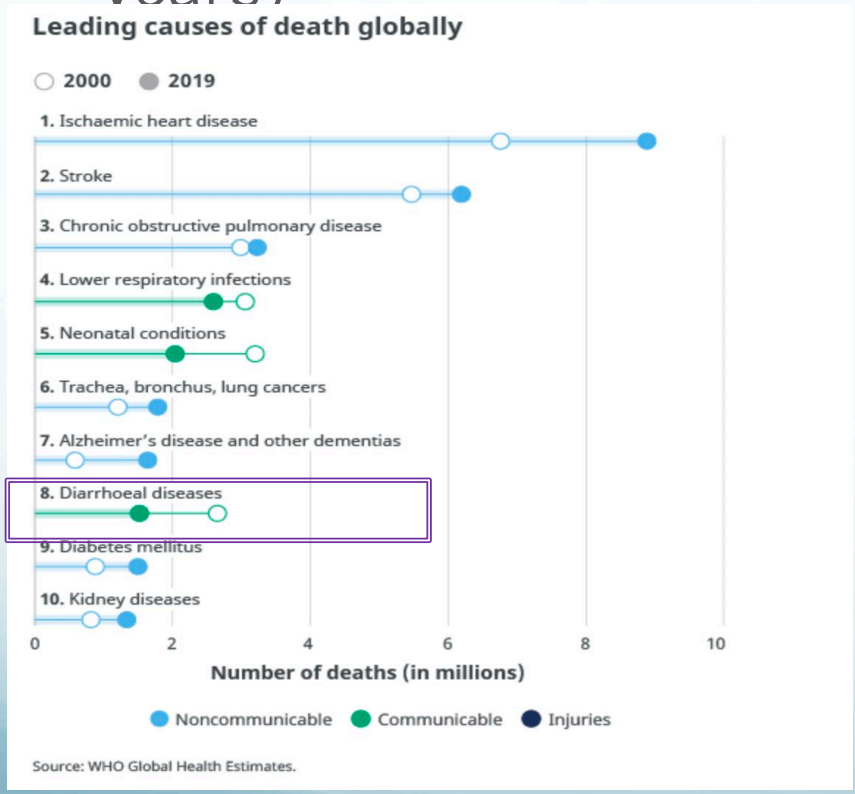
Disclosures

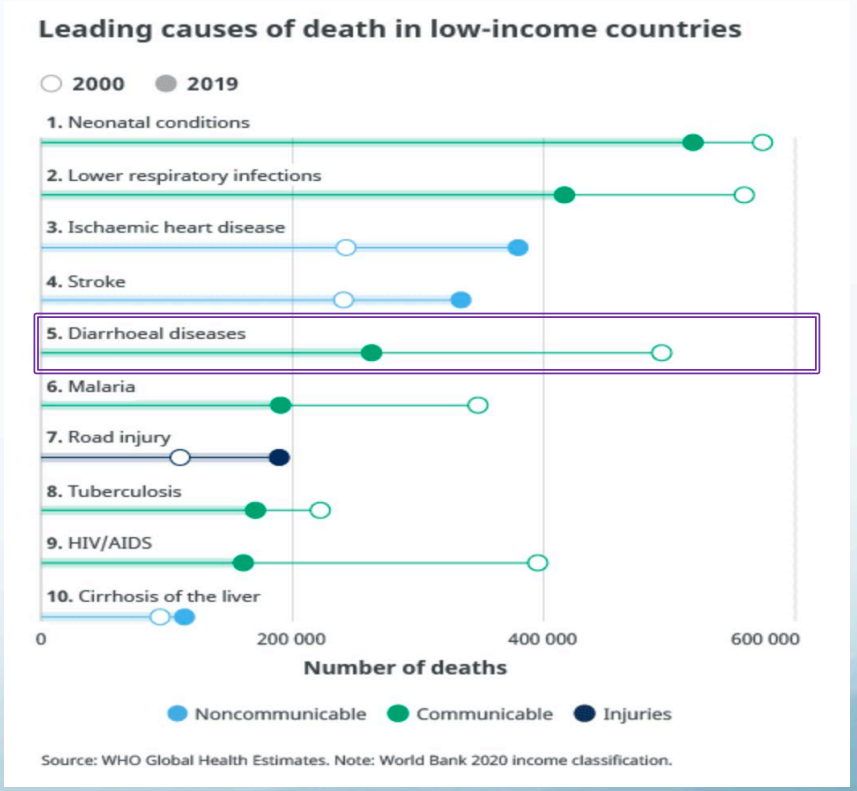
- US National Institutes of Health (NIH) National Institute of Diabetes and Digestive and Kidney Diseases (R01)
  - Role: PI, $2,809,435 total costs
- US NIH Fogarty International Center (K01)
  - Role: PI, $679,529 total cost
- Thrasher Foundation
  - Role: PI, $25,000 total costs
- Brown University Department of Emergency Medicine
  - Role: PI, $46,086 total costs
- Rhode Island Foundation
  - Role: PI, $15,000 total costs

Background

Global Burden of Diarrheal Disease

- 6.5 billion cases of diarrhea and 1.4 million deaths in 2019 (3/4 cases & 2/3 deaths in patients > 5 years)

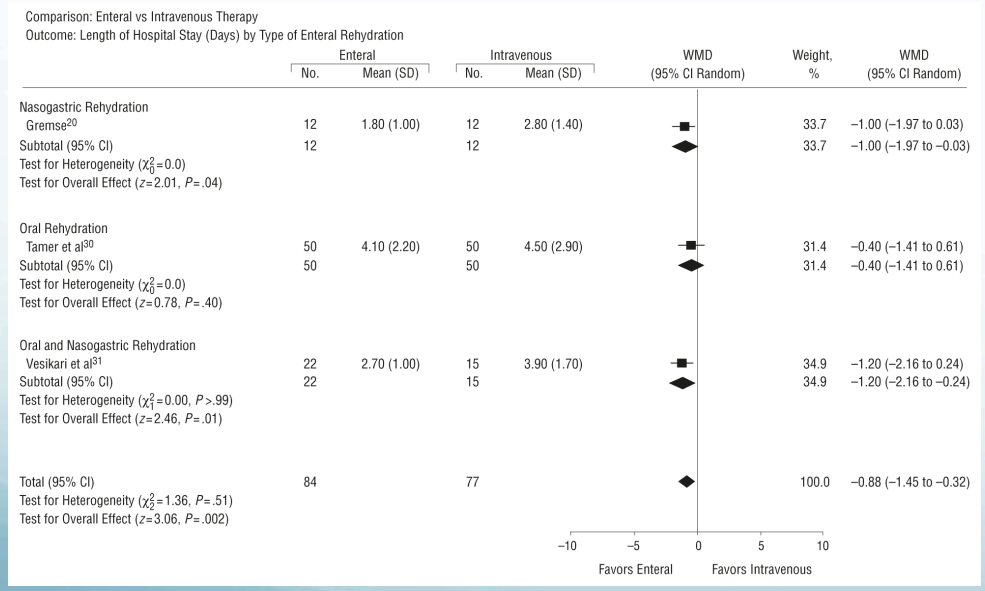


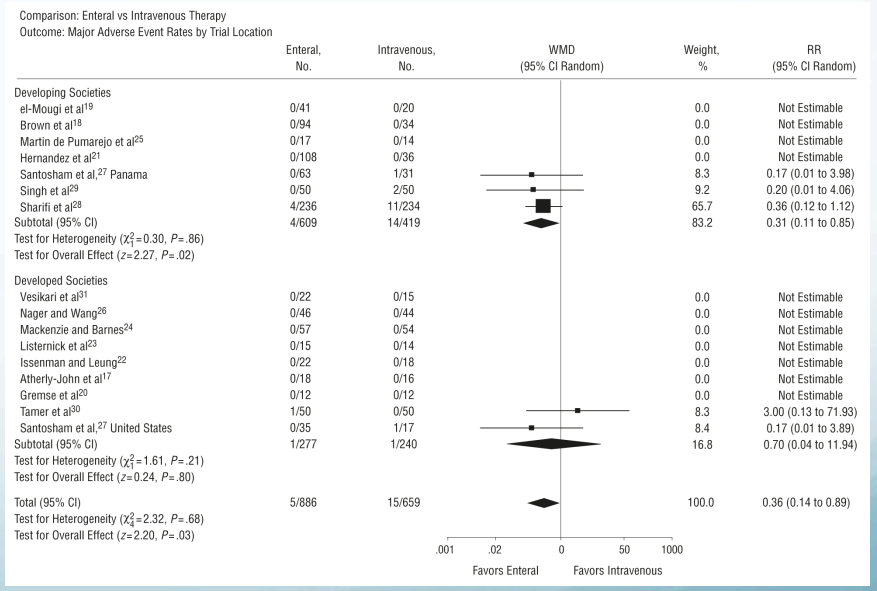


Vos T,, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396(10258):1204–22.

Diarrhea Case Management

- Accurate assessment of dehydration and appropriate rehydration are the most important components of diarrhea management, as both under- and over-treatment can have serious consequences





Fonseca B, Holdgate A, Craig J. Enteral vs intravenous rehydration therapy for children with gastroenteritis: a meta-analysis of randomized controlled trials. Arch Pediatr Adolesc Med. 2004; 158(483):90.

Dehydration Assessment Tools

- Few empirically derived tools exist for assessing dehydration in young children with diarrhea but none were validated in low resource settings
- No empirically derived tools exist for assessing dehydration in older children or adults
- WHO recommends using a four symptom algorithm for assessing dehydration in children and adults, developed based on expert opinion but never validated against a physiological gold standard

Goldman R, Friedman J, Parkin P. Validation of the clinical dehydration scale for children with acute gastroenteritis. Pediatrics. 2008; 122(545):9.

WHO IMCI Guidelines

Two of the following signs: ● Lethargic or unconscious ● Sunken eyes ● Not able to drink or drinking poorly ● Skin pinch goes back very slowly	SEVERE DEHYDRATION	➤ If child has no other severe classification: — Give fluid for severe dehydration (Plan C). OR If child also has another severe classification: — Refer URGENTLY to hospital with mother giving frequent sips of ORS on the way. Advise the mother to continue breastfeeding ➤ If child is 2 years or older and there is cholera in your area, give antibiotic for cholera.
Two of the following signs: ● Restless, irritable ● Sunken eyes ● Drinks eagerly, thirsty ● Skin pinch goes back slowly	SOME DEHYDRATION	➤ Give fluid and food for some dehydration (Plan B). ➤ If child also has a severe classification: — Refer URGENTLY to hospital with mother giving frequent sips of ORS on the way. Advise the mother to continue breastfeeding ➤ Advise mother when to return immediately. ➤ Follow-up in 5 days if not improving.
Not enough signs to classify as some or severe dehydration.	NO DEHYDRATION	➤ Give fluid and food to treat diarrhoea at home (Plan A). ➤ Advise mother when to return immediately. ➤ Follow-up in 5 days if not improving.

Integrated Management of Childhood Illness Guidelines. WHO 2005.

WHO IMAI Guidelines

Two of the following signs: • Lethargic or unconscious • Sunken eyes • Not able to drink or drinking poorly • Skin pinch goes back very slowly	**SEVERE DEHYDRATION**	• If no other severe classification, give fluid for severe dehydration, (Plan C on p. 90) then reassess. (This patient may not require referral.) **Or, if another severe classification:** • **Refer URGENTLY to hospital after initial IV hydration or, if not possible, with frequent sips of ORS on the way.** **If there is cholera in your area, give appropriate antibiotic for cholera (according to sensitivity data).**
Two of the following signs: • Sunken eyes • Drinks eagerly, thirsty • Skin pinch goes back slowly	**SOME DEHYDRATION**	• Give fluid and food for some dehydration. (See Plan B on p. 89.) • Advise when to return immediately. • Follow up in 5 days if not improving.
Not enough signs to classify as some or severe dehydration	**NO DEHYDRATION**	• Give fluid and food to treat diarrhoea at home. (See Plan A on p. 88.) • Advise when to return immediately. • Follow up in 5 days if not improving.

Integrated Management of Adult Illness Guidelines. WHO 2005.

Plan A: Expectant Management

- Continue to breastfeed (infants) and offer extra breastmilk
- Continue to feed older patients and offer plenty of extra fluids (not specifically ORS)
- Provide instructions to return for fever, bloody diarrhea, drinking poorly, or diarrhea > 14 days

Plan B: Oral Rehydration at Health Center

Plan C: Intravenous Rehydration in Hospital

Measuring Dehydration

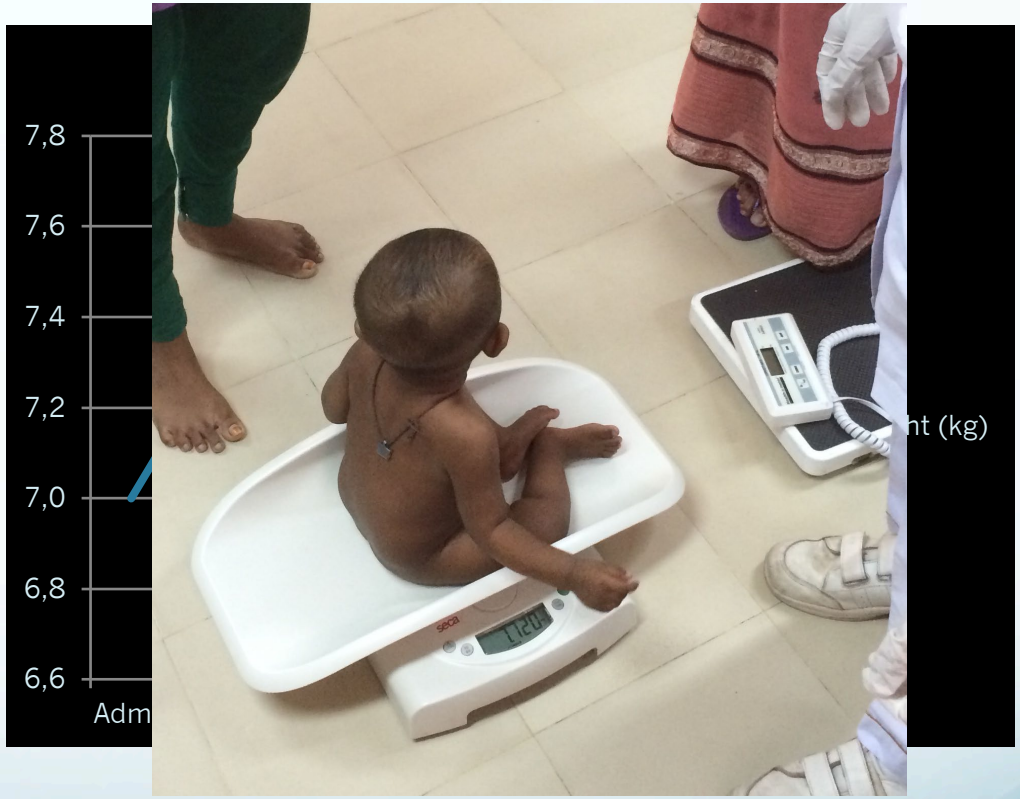
Criterion (Gold) Standard

- Dehydration = Loss of Water/Salt in Diarrhea
- 1 liter of water weighs 1 kilogram
- Ideal measure =

$$\frac{\text{Healthy Weight} - \text{Sick Weight}}{\text{Healthy Weight}}$$

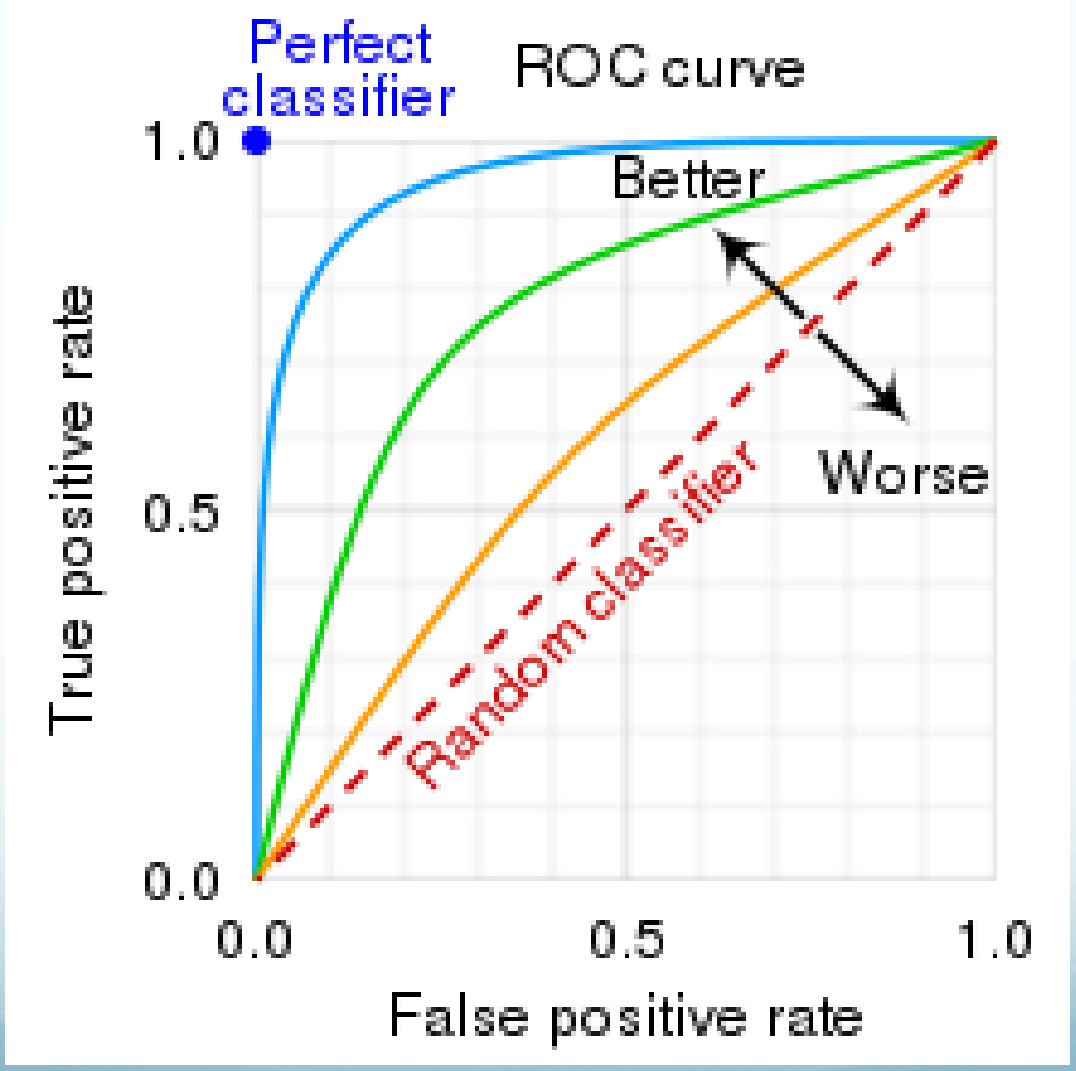
Criterion (Gold) Standard

- Problem: We don't know the healthy pre-illness weight
- Use stable post-hydration/recovery weight instead
- Excellent correlation: 0.979 - 0.999



Gorelick, M. H., K. N. Shaw, et al. (1997). "Validity and reliability of clinical signs in the diagnosis of dehydration in children." Pediatrics 99(5): E6.
Hooper L, et al. Clinical symptoms, signs and tests for identification of impending and current water-loss dehydration in older people. Cochrane Database Syst Rev. 2015;2015:4.

Brief ROC Curve Tutorial



Prior Evidence: Children Under Five Years

Canada

- Derivation study of 102 children age 1-36 months with acute diarrhea presenting to single pediatric ED; 10% with at least moderate (>6%) dehydration
- Evaluated 12 clinical signs and found combination of 4 performed the best, with area under ROC curve (AUC) of 0.83 (95% CI: 0.77-0.88)

TABLE 1 CDS[10]

Characteristic	Score of 0	Score of 1	Score of 2
General appearance	Normal	Thirsty, restless, or lethargic but irritable when touched	Drowsy, limp, cold, or sweaty; comatose or not
Eyes	Normal	Slightly sunken	Very sunken
Mucous membranes (tongue)	Moist	Sticky	Dry
Tears	Tears	Decreased tears	Absent tears

Friedman JN, et al. Development of a clinical dehydration scale for use in children between 1 and 36 months of age. J Pediatr, 2004; 145:201-7.

Canada/Switzerland

- External validation study of 264 children under five years with acute diarrhea presenting to 3 hospitals in Montreal, Quebec City and Geneva
- CDS was able to classify children relatively well with mild dehydration (X^2=11,513, p<0.003) and moderate dehydration (X^2=36,436, p<0.001)

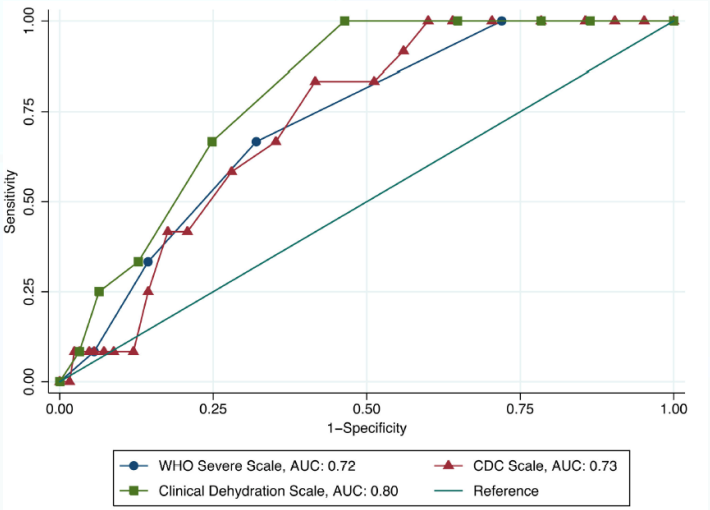
Tableau II
Association entre le score clinique de déshydratation pédiatrique (SCD) et la déshydratation calculée à l'aide du gain de poids après récupération clinique (*n* = 219 participants).

SCD	*n*	Reprise de moins de 3 % de son poids : *n* (%)	Reprise entre 3 et 6 % de son poids : *n* (%)	Reprise de plus de 6 % de son poids : *n* (%)
0	64	50 (78)	7 (11)	7 (11)
1 à 4	141	98 (70)	30 (21)	13 (9)
5 à 8	14	2 (14)	3 (21)	9 (64)
Total	219	150	40	29

Gravel J, Manzano S, Guimont C, Lacroix L, Gervaix A, Bailey B. Validation multicentrique du score clinique de déshydratation pédiatrique. *Arch Pediatr* 2010; **17:** 1645–51.

Rwanda

- 136 children presenting with acute diarrhea to 3 rural hospitals in Rwanda; 10% with severe (>9%) dehydration or death
- CDS and WHO IMCI performed relatively well when used by doctors
- When used by nurses, CDS and WHO IMCI accuracy dropped, with AUC of 0.65 for WHO IMCI



Clinical scale	Area under ROC curve	95% confidence interval lower bound	95% confidence interval upper bound
Full Cohort			
WHO Severe Scale	0.722	0.598	0.846
CDC Scale	0.726	0.616	0.836
Clinical Dehydration Scale	0.801	0.710	0.892
Scale Recorded by Nurse			
WHO Severe Scale	0.651	0.470	0.833
CDC Scale	0.607	0.423	0.790
Clinical Dehydration Scale	0.778	0.632	0.925
Scale Recorded by Doctor			
WHO Severe Scale	0.780	0.602	0.959
CDC Scale	0.827	0.683	0.972
Clinical Dehydration Scale	0.830	0.720	0.940

Levine AC, et al. Prediction of severe disease in children with diarrhea in a resource-limited setting. PLoS One. 2013 Dec 3;8(12):e82386.

Dehydration: Assessing Kids Accurately (DHAKA) Study

Study Objectives

- Derive a new clinical diagnostic model for use by nurses and other less skilled providers to assess the severity of dehydration in children under five years with acute diarrhea in a resource-limited setting
- Validate the new model in a new population of children and compare its accuracy and reliability to the current World Health Organization Integrated Management of Childhood Illness (IMCI) Guidelines

Study Setting and Population

DATE & DAY / TIME	20.04.13 SAT	21.04.13 SUN	22.04.13 MON	23.04.13 TUE	24.04.13 WED
AT 01:00	02	14	11	14	09
" 02:00	04	23	22	23	18
" 03:00	09	26	27	29	25
" 04:00	12	32	30	32	32
" 05:00	14	37	35	36	38
" 06:00	24	43	38	37	45
" 07:00	36	50	45	49	54
" 08:00	56	72	55	57	64
" 09:00	75	94	68	70	83
" 10:00	107	115	79	90	98
" 11:00	132	146	97	112	119
" 12:00	169	175	119	135	147
" 13:00	190	196	141	155	158
" 14:00	219	224	170	174	178
" 15:00	241	243	190	193	199
" 16:00	266	267	207	210	225
" 17:00	291	293	226	224	241
" 18:00	304	305	242	234	253
" 19:00	324	318	254	249	274
" 20:00	335	333	270	266	290
" 21:00	356	343	279	273	316
" 22:00	375	361	293	282	325
" 23:00	388	374	303	295	346
" 23:59	401	388	320	307	364

- Provides free care to urban/rural population of 17 million people

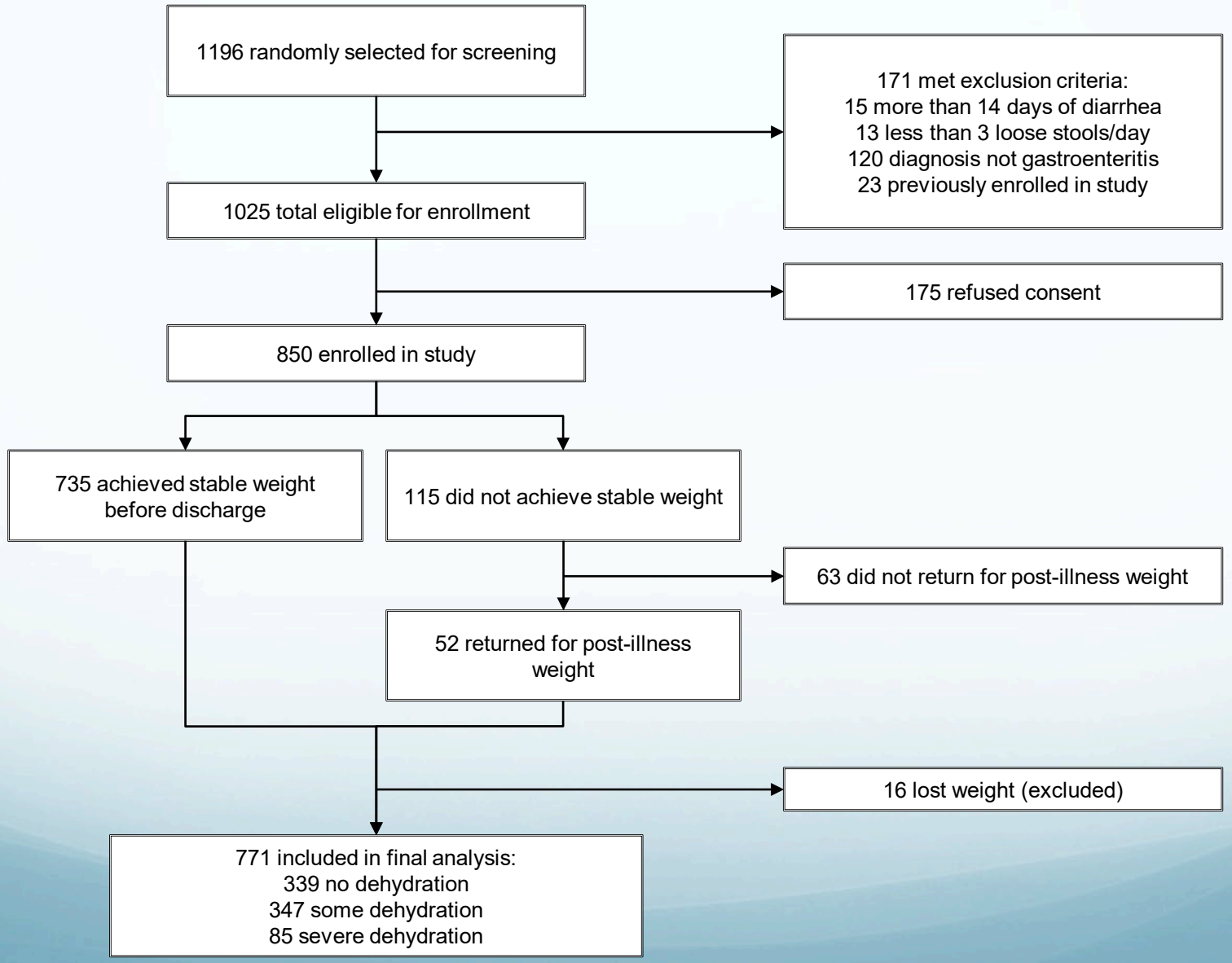
Random Selection/Consent

Baseline Weight

Clinical Exam


Rehydration Unit

Derivation Study Flow Diagram



Clinical Predictors

- General Appearance
- Sunken Eyes
- Heart Rate
- Mucous Membranes
- Radial Pulse
- Respirations
- Skin Pinch
- Tears
- Capillary Refill
- Extremities

Clinical Predictors

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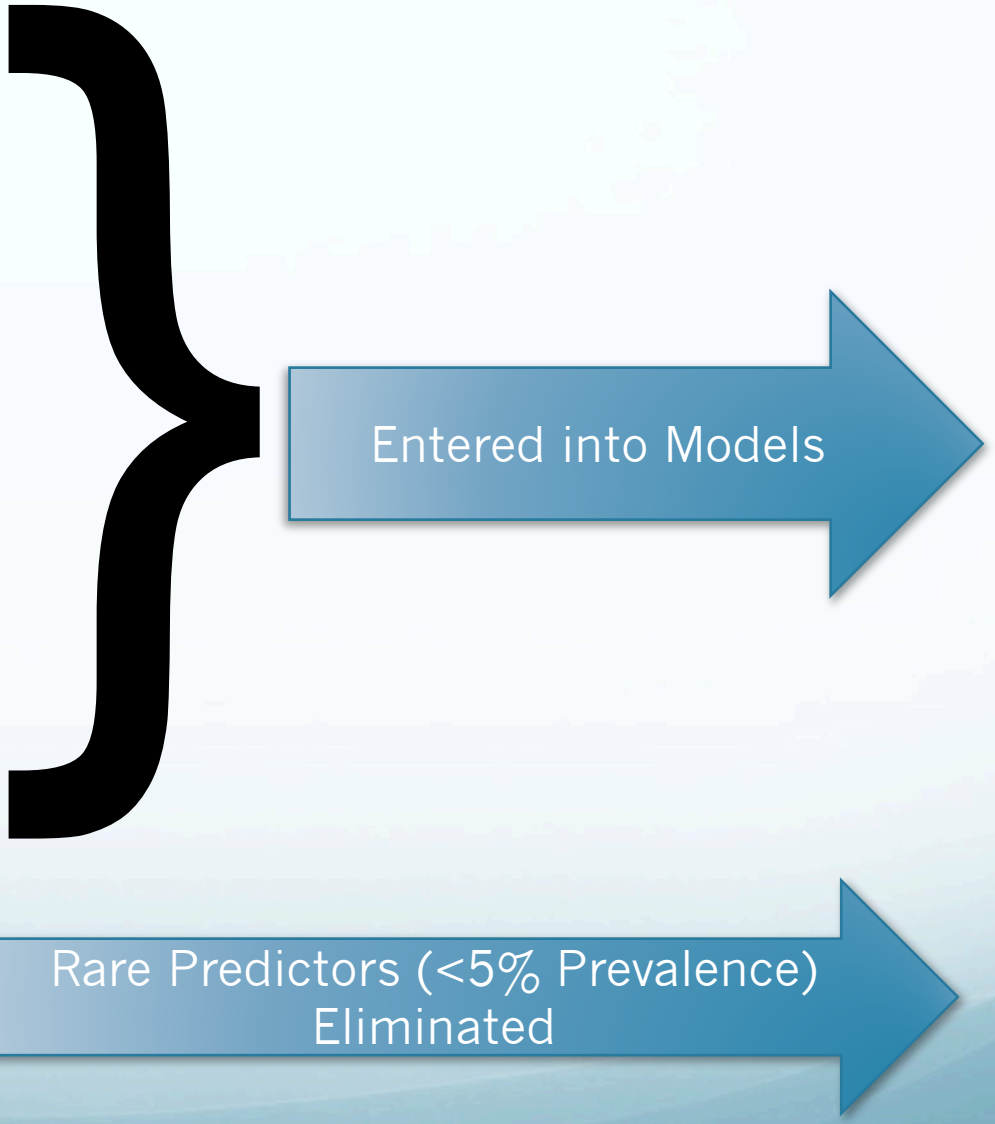
- ~~Extremities~~

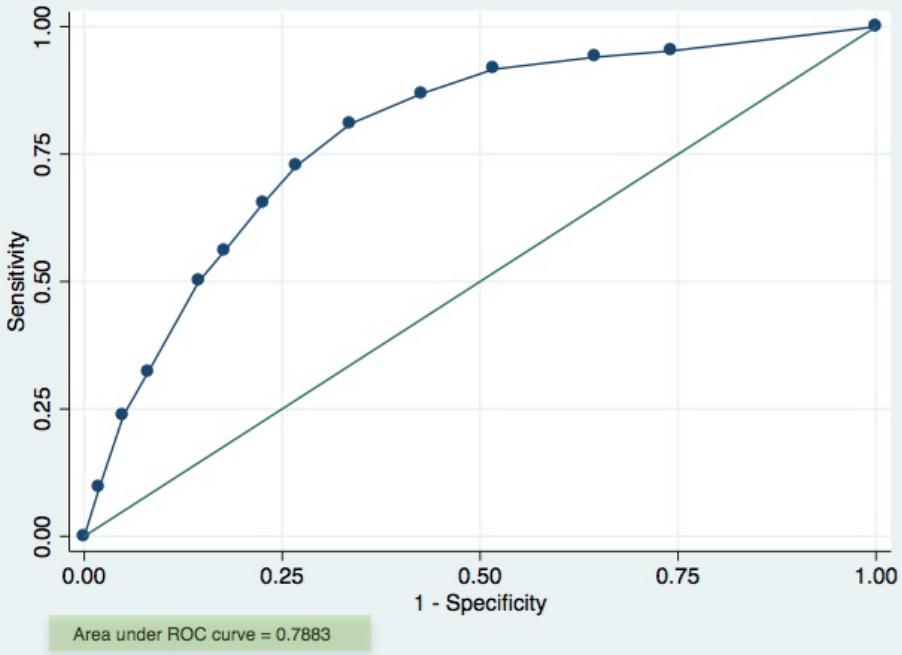


Final DHAKA Score

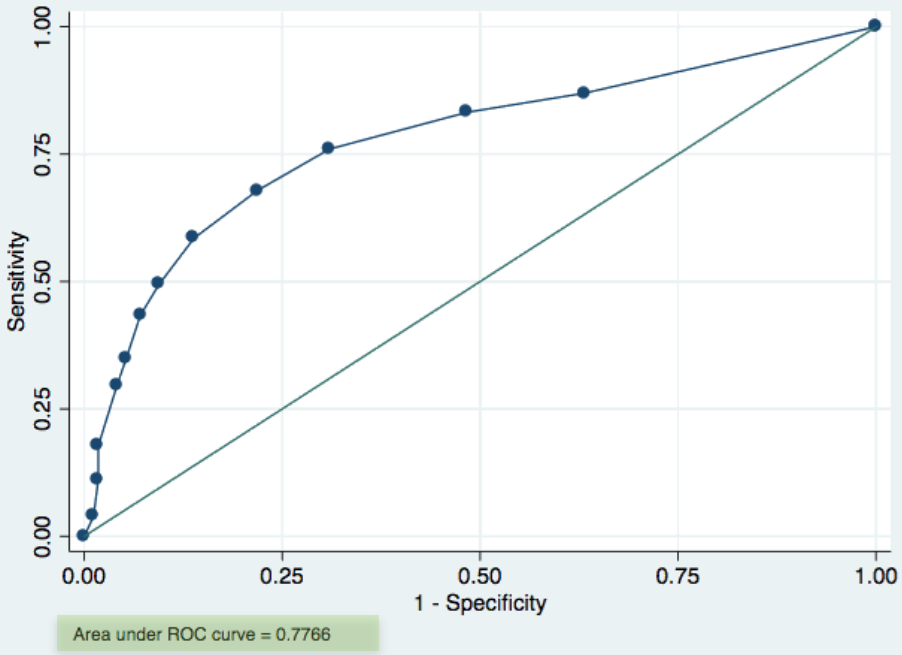
Clinical Sign	Finding	Score
General Appearance	Normal	0
	Restless/Irritable	2
	Lethargic/Unconscious	4
Respirations	Normal	0
	Deep	2
Skin Pinch	Normal	0
	Slow	2
	Very Slow	4
Tears	Normal	0
	Decreased	1
	Absent	2

Accuracy of DHAKA Score

Severe Dehydration



Some Dehydration



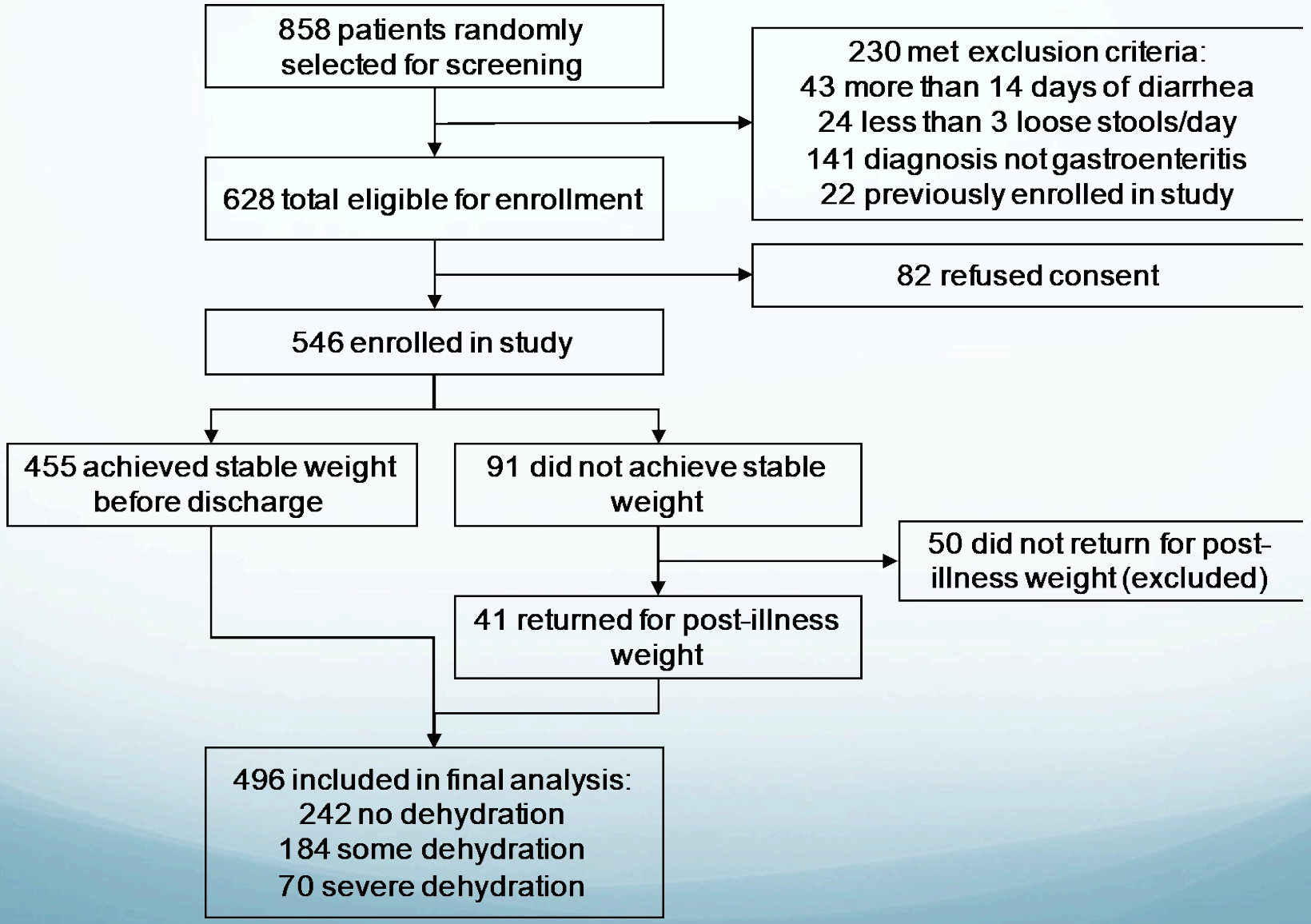
Levine AC, et al. Empirically Derived Dehydration Scoring and Decision Tree Models for Children With Diarrhea: Assessment and Internal Validation in a Prospective Cohort Study in Dhaka, Bangladesh. Glob Health Sci Pract. 2015 Aug 18;3(3):405-18.

DHAKA Score Test Characteristics

	Sensitivity	Specificity	LR+	LR-
Severe Dehydration (cutoff > 4)	87%	57%	2.0	0.23
Some Dehydration (cutoff > 2)	83%	52%	1.7	0.33

Levine AC, et al. Empirically Derived Dehydration Scoring and Decision Tree Models for Children With Diarrhea: Assessment and Internal Validation in a Prospective Cohort Study in Dhaka, Bangladesh. Glob Health Sci Pract. 2015 Aug 18;3(3):405-18.

Validation Study Flow Diagram



DHAKA Score vs. WHO IMCI

- Accuracy
  - DHAKA score ordinal c-index: 0.82 (95% CI: 0.78, 0.85)
  - WHO algorithm ordinal c-index: 0.76 (95% CI: 0.73, 0.79)
  - DHAKA outperformed IMCI ($p<0.001$)
- Reliability
  - DHAKA score weighted kappa statistic: 0.92
  - WHO algorithm weighted kappa statistic: 0.81
- Bottom Line
  - Universal use of the DHAKA score would detect an additional **436,400** cases of severe dehydration in young children currently being missed by WHO IMCI

Levine AC, et al. External validation of the DHAKA score and comparison with the current IMCI algorithm for the assessment of dehydration in children with diarrhoea: a prospective cohort study. Lancet Glob Health. 2016 Oct;4(10):e744-51. Lamberti L, Fischer Walker C, Black R. Systematic review of diarrhea duration and severity in children and adults in low- and middle-income countries. *BMC Public Health*. 2012;12:276.

External validation of the DHAKA score and comparison with the current IMCI algorithm for the assessment of dehydration in children with diarrhoea: a prospective cohort study

Adam C Levine, Justin Glavis-Bloom, Payal Modi, Sabiha Nasrin, Bita Atika, Soham Rege, Sarah Robertson, Christopher H Schmid, Nur H Alam

Summary

Background Dehydration due to diarrhoea is a leading cause of child death worldwide, yet no clinical tools for assessing dehydration have been validated in resource-limited settings. The Dehydration: Assessing Kids Accurately (DHAKA) score was derived for assessing dehydration in children with diarrhoea in a low-income country setting. In this study, we aimed to externally validate the DHAKA score in a new population of children and compare its accuracy and reliability to the current Integrated Management of Childhood Illness (IMCI) algorithm.

Methods DHAKA was a prospective cohort study done in children younger than 60 months presenting to the International Centre for Diarrhoeal Disease Research, Bangladesh, with acute diarrhoea (defined by WHO as three or more loose stools per day for less than 14 days). Local nurses assessed children and classified their dehydration status using both the DHAKA score and the IMCI algorithm. Serial weights were obtained and dehydration status was established by percentage weight change with rehydration. We did regression analyses to validate the DHAKA score and compared the accuracy and reliability of the DHAKA score and IMCI algorithm with receiver operator characteristic (ROC) curves and the weighted κ statistic. This study was registered with ClinicalTrials.gov, number NCT02007733.

Findings Between March 22, 2015, and May 15, 2015, 496 patients were included in our primary analyses. On the basis of our criterion standard, 242 (49%) of 496 children had no dehydration, 184 (37%) of 496 had some dehydration, and 70 (14%) of 496 had severe dehydration. In multivariable regression analyses, each 1-point increase in the DHAKA score predicted an increase of 0·6% in the percentage dehydration of the child and increased the odds of both some and severe dehydration by a factor of 1·4. Both the accuracy and reliability of the DHAKA score were significantly greater than those of the IMCI algorithm.

Interpretation The DHAKA score is the first clinical tool for assessing dehydration in children with acute diarrhoea to be externally validated in a low-income country. Further validation studies in a diverse range of settings and paediatric populations are warranted.

Lancet Glob Health 2016

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See Online/Comment
http://dx.doi.org/10.1016/S2214-109X(16)30179-6

Warren Alpert Medical School of Brown University, Providence, RI, USA (A C Levine MD, J Glavis-Bloom MD, S Rege BS); **Department of Biostatistics, Brown University School of Public Health, Providence, RI, USA** (S Robertson MS, C H Schmid PhD); **University of Massachusetts Medical School, Worcester, MA, USA** (P Modi MD); **and International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh** (S Nasrin MBBS, B Atika MBBS, N H Alam MD)

Correspondence to:
Adam C Levine, Warren Alpert Medical School of Brown University, Providence, RI 02903, USA
adam_levine@brown.edu

Novel, Innovative Research for Understanding Dehydration in Adults and Kids (NIRUDAK) Study

Study Objectives

Specific Aim 1

- Employ machine learning techniques to derive and internally validate age specific clinical diagnostic models for assessing dehydration severity and volume deficit in patients over five years of age
- Conduct various secondary analyses, including for cholera patients specifically


Specific Aim 2a

- Utilize formative research to develop a new mHealth tool


Specific Aim 2b

- Validate the accuracy, reliability, and usability of the newly developed and refined mHealth tool


Study Setting and Population

Patients randomly selected at triage, 24 hours/day, 7 days a week, and consented

Inclusion Criteria

- Age over 5 years
- Present at triage with diarrhea

Exclusion Criteria

- Chronic diarrhoea (greater than 7 days)
- Less than 3 loose stools/day
- Clear alternative diagnosis to gastroenteritis
- Previously enrolled in NIRUDAK Study

Data Collection

CASE REPORT FORM #2
CLINICAL EXAM

PLEASE PLACE STUDY BARCODE LABEL HERE

NURSE PERFORMING EXAM NAME: _____

EXAM TIME: _ _:_ _ (HH:MM, 24 hour time)

TEMPERATURE: _ _ _._ ^{0}F		**RESPIRATION RATE:** _ _ _	
HEART RATE (Flat): _ _ _		**BLOOD PRESSURE (Flat):** _ _ _/_ _ _	
HEART RATE (Sitting): _ _ _		**BLOOD PRESSURE (Sitting):** _ _ _/_ _ _	
MENTAL STATUS:	(Normal)	(Confused/Lethargic)	(Unconscious)
THIRST:	(Normal)	(Drinks Eagerly)	(Refuses/Unable To Drink)
SKIN PINCH:	(Rapid)	(Slow)	(Very Slow)
EYES:	(Normal)	(Sunken Eyes)	
MUCOUS MEMBRANES:		(Moist)	(Dry)
RESPIRATIONS:		(Normal)	(Deep)
RADIAL PULSE:	(Strong)	(Decreased)	(Absent)
CAPILLARY REFILL:		(Normal)	(Prolonged)
URINE OUTPUT (8 hours):		(Normal)	(Decreased/Dark) (Minimal/None)

Analysis of Outcomes

Analysis of Outcome: Percent Dehydration

$$\text{Percent Dehydration} = \frac{\text{Post-Illness Weight} - \text{Admission Weight}}{\text{Post-Illness Weight}} \times 100$$

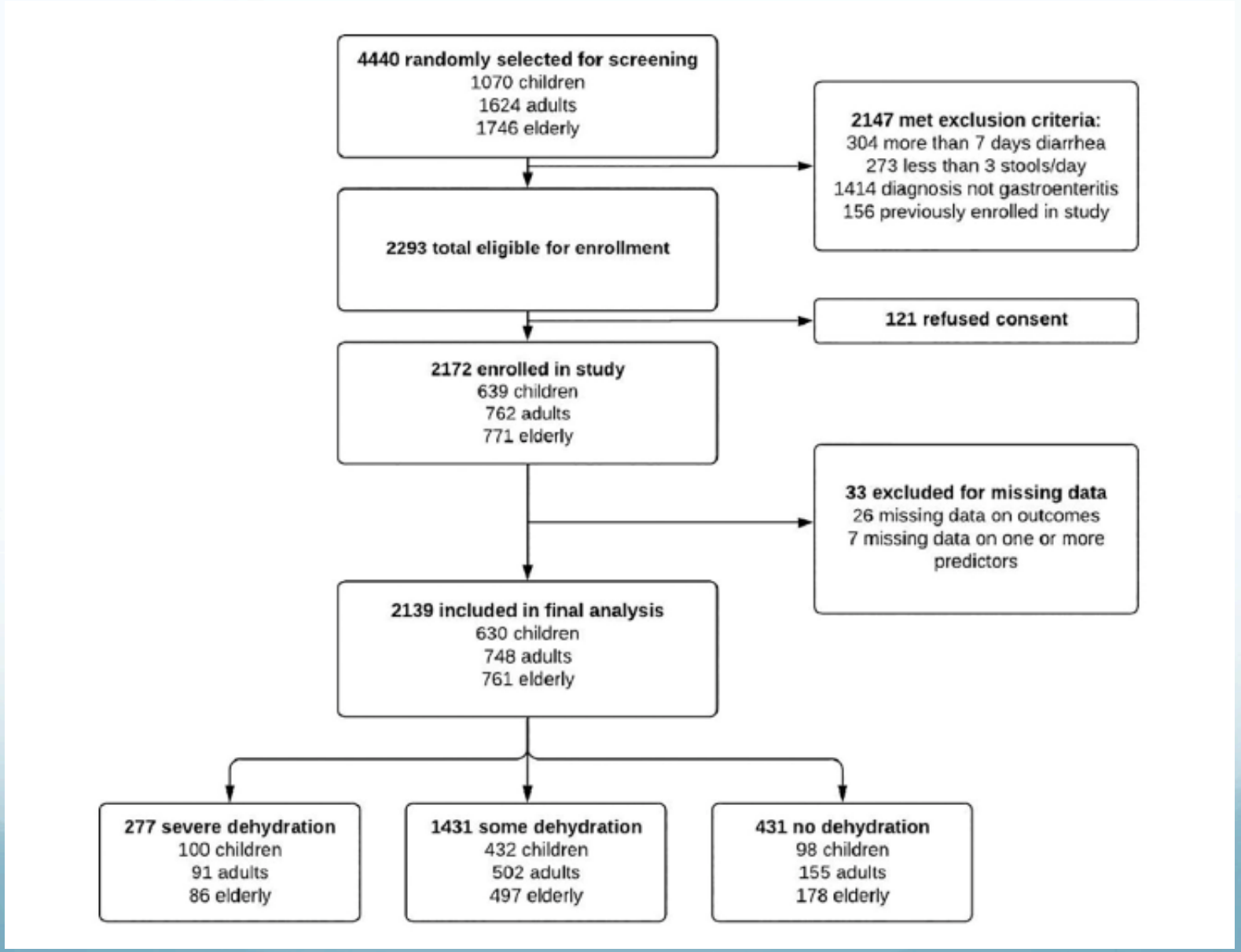
Dehydration Category

- **Severe Dehydration:** >9%
- **Some Dehydration:** 3 – 9%
- **No Dehydration**: <3%

Analysis of Outcome: Volume Deficit

$$\text{Volume Deficit} = \text{Percent Dehydration} \times \text{Healthy Weight}$$

Derivation Study Flow Diagram



Data Analysis

Derivation of Clinical Diagnostic Models

Age Specific Models
- Older Children: 5 – 19 years
- Adults: 20 – 59 years
- Older Adults: 60+ years

Full NIRUDAK Model
- Age
- Sex
- 16 Clinical Predictors

Simple NIRUDAK Model
- 9 clinical predictors (no equipment required)

Forward Stepwise Regression Techniques

- Explored models with and without interactions and cubic splines
- Selected the best model size via 10-fold cross validation
- Optimal model size was chosen with lowest average log likelihood
- Final model developed by applying forward stepwise regression to dataset

Ordinal regression models to predict dehydration severity (none/some/severe)

Linear regression models to predict total fluid volume deficit (in liters)

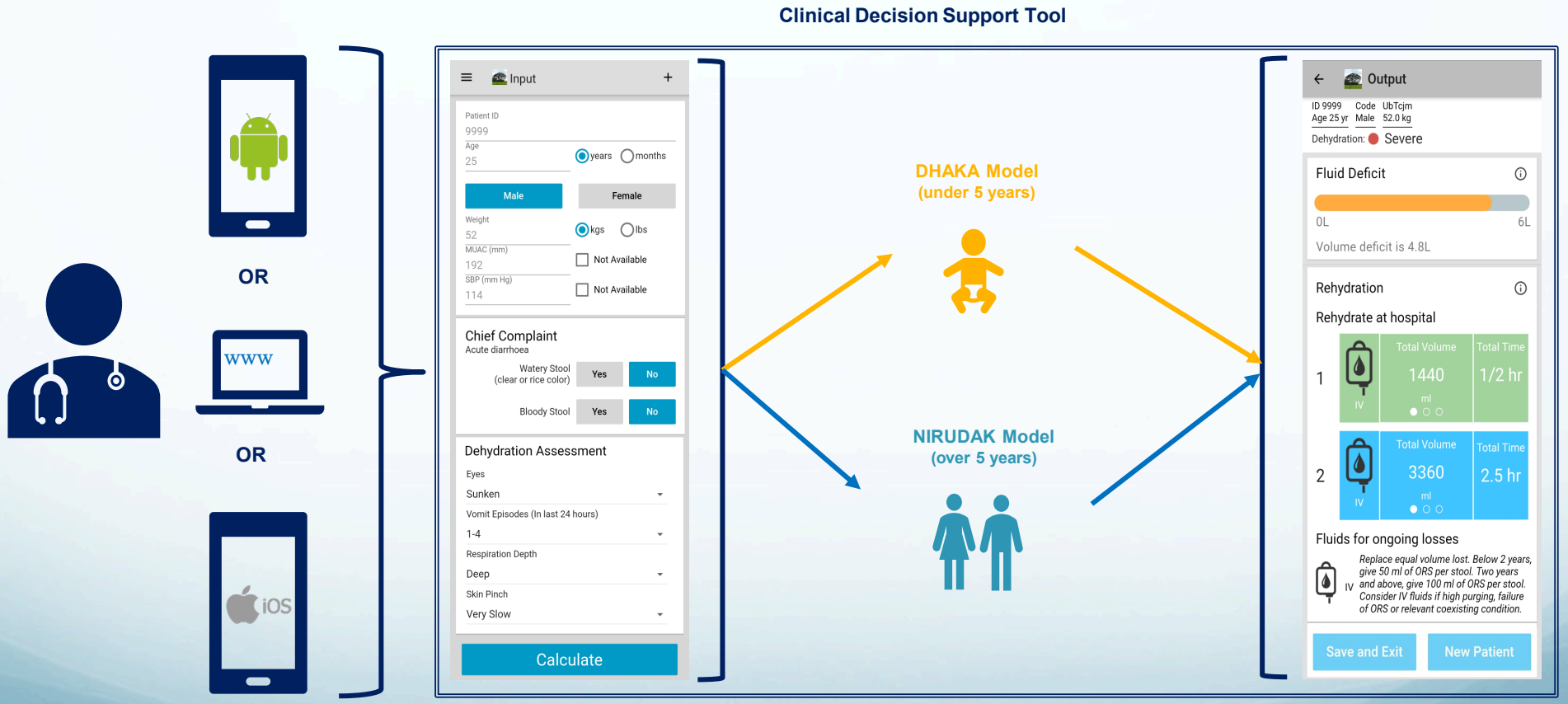
Final Variables Selected

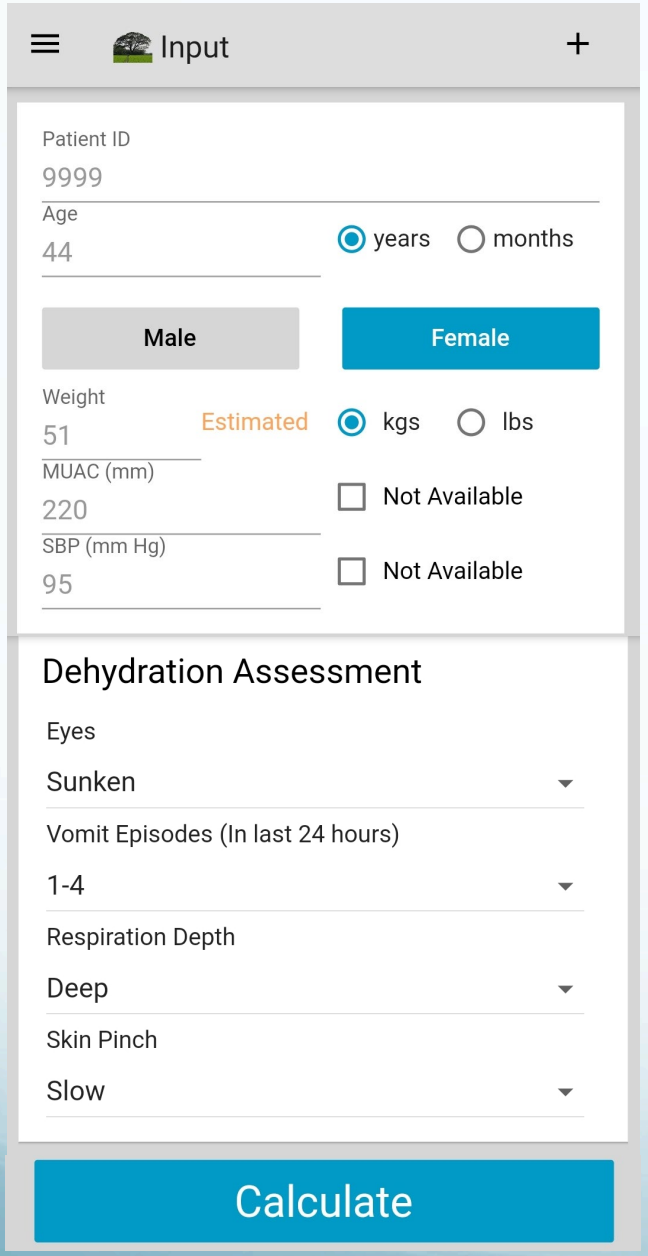
Full Model	Older Child (5-19)	Adult (20-59)	Older Adult (60-100)	Simple Model
Skin Pinch	Sk	Skin Pinch	Pinch	Skin Pinch
Eye Level	Eye	Eye Leve		Eye Level
Respiration Depth	Respirat Depth		Respiration Depth	Respiration Depth
# Vomiting Episodes	# Vomiting Episodes		# Vomiting Episodes	
Systolic BP	Diastolic BP	BP	Systolic BP	
	Heart Rate			Radial Pulse
MUAC	MUAC	MU	MUAC	
Sex	Diarr Du		Sex	
Age	# Episodes			Urine Output

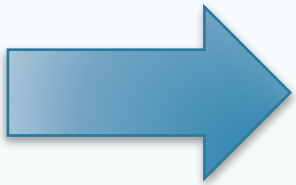
Qualitative Methods: Formative Research

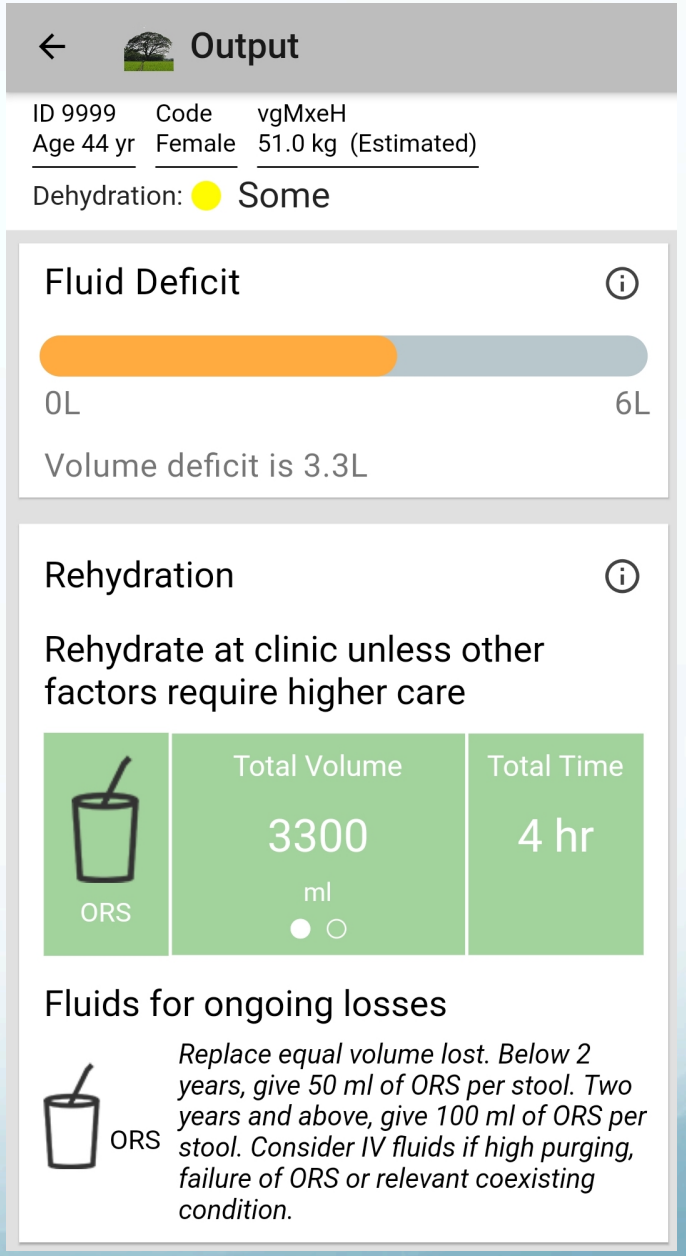
- 8 focus groups Nov & Dec 2020
  - 4 with physicians & 4 with Nurses
  - 4 at icddr,b & 4 at district/subdistrict hospitals
- Focus groups conducted via zoom, in Bangla, with facilitation by icddr,b research partners
- Framework matrix analysis for app development
- Data collected on:
  - Optimal User Interface and Output Screens
  - Balance of sensitivity versus specificity
  - Additional components (danger signs, antibiotics, etc)

www.FluidCalc.org




Input
Patient ID
9999
Age
44
years
months
Male
Female
Weight
51
Estimated
kgs
lbs
MUAC (mm)
220
Not Available
SBP (mm Hg)
95
Not Available
Dehydration Assessment
Eyes
Sunken
Vomit Episodes (In last 24 hours)
1-4
Respiration Depth
Deep
Skin Pinch
Slow
Calculate



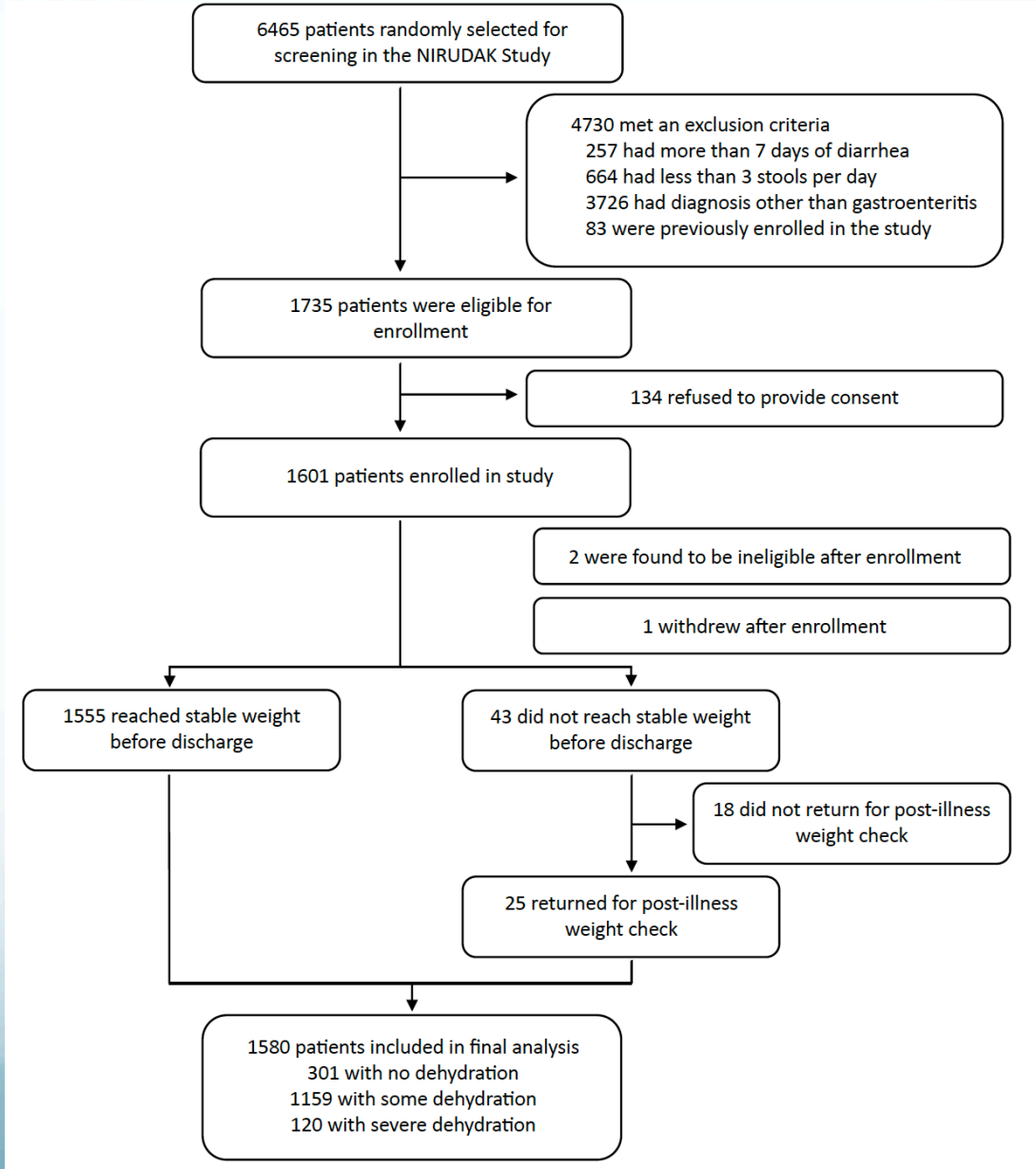

Output
ID 9999
Code
vgMxeH
Age 44 yr
Female
51.0 kg (Estimated)
Dehydration:
Some
Fluid Deficit
0L
6L
Volume deficit is 3.3L
Rehydration
Rehydrate at clinic unless other factors require higher care
ORS
Total Volume
3300
ml
Total Time
4 hr
Fluids for ongoing losses
ORS
Replace equal volume lost. Below 2 years, give 50 ml of ORS per stool. Two years and above, give 100 ml of ORS per stool. Consider IV fluids if high purging, failure of ORS or relevant coexisting condition.

Simplified NIRUDAK Score

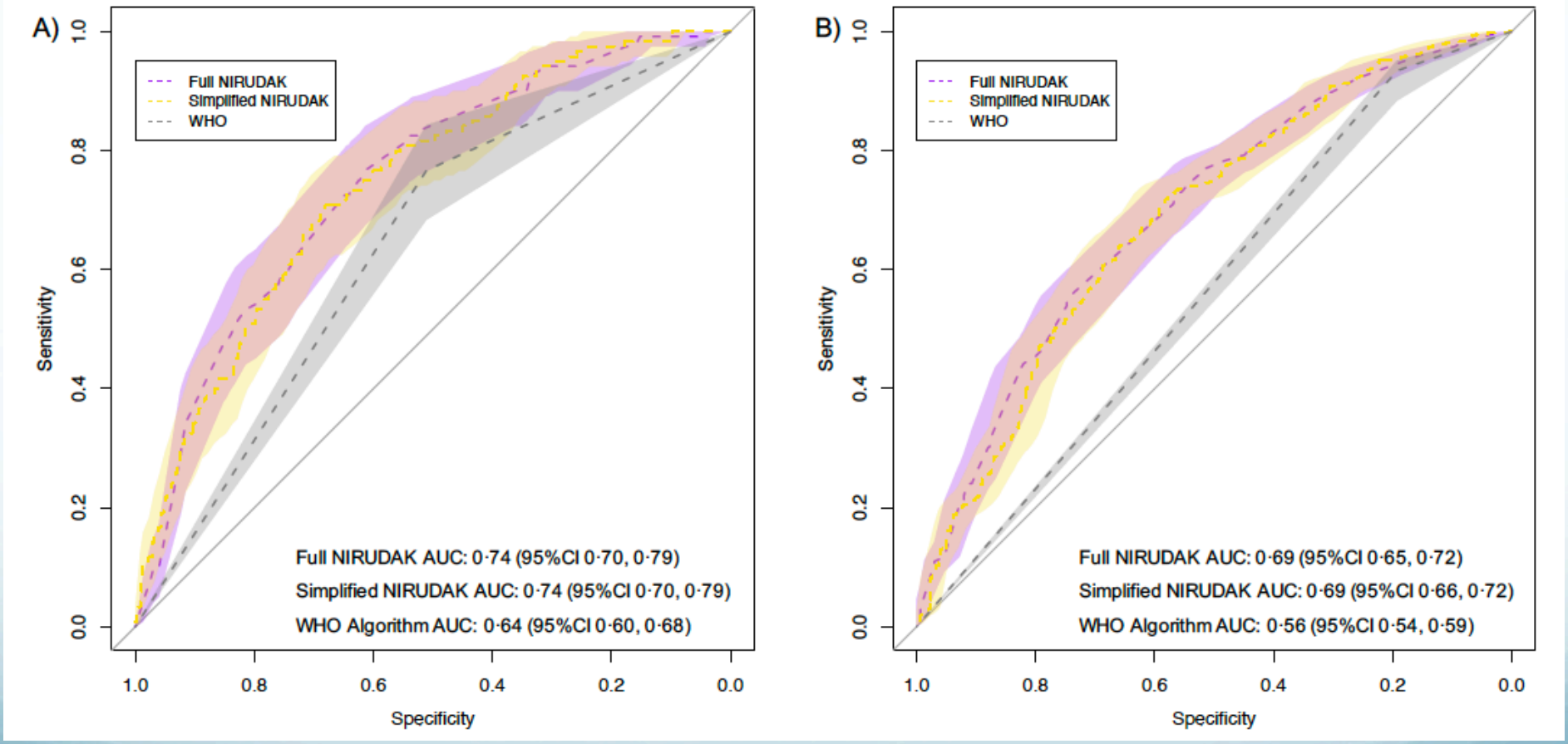
	Points
Skin pinch	
Rapid	0
Slow	2
Very slow	4
Eye level	
Normal	0
Sunken	2
Respiration depth	
Normal	0
Deep	2
Urine output	
Normal	0
Decreased or dark	1
Minimal or none	2
Radial pulse	
Strong	0
Decreased	1
Absent	4

Suggested scoring: <4=no dehydration, 4–6=some dehydration, >6=severe dehydration.

Validation Study Flow Diagram



Accuracy of NIRUDAK Models for Severe Dehydration



Levine AC, et al. Derivation of the First Clinical Diagnostic Models for Dehydration Severity in Patients over Five Years with Acute Diarrhea. PLoS Negl Trop Dis. 2021 Mar 10;15(3):e0009266.

NIRUDAK Score vs WHO IMAI Test Characteristics

	NIRUDAK		WHO	
	Sensitivity	Specificity	Sensitivity	Specificity
Severe Dehydration	83%	52%	77%	51%
Some Dehydration	90%	30%	93%	19%

NIRUDAK vs. WHO IMAI

- Accuracy for Predicting Dehydration Category
  - Full NIRUDAK ORC: 0.74 (95% CI: 0.71, 0.77)
  - Simple NIRUDAK ORC: 0.75 (95% CI: 0.71, 0.78)
  - WHO IMAI ORC: 0.64 (95% CI: 0.61, 0.67)
- Reliability
  - Full NIRUDAK ICC: 0.98 (95% CI: 0.97, 0.98)
  - Simple NIRUDAK ICC: 0.94 (95% CI: 0.93, 0.95)
  - WHO algorithm ICC: 0.56 (95% CI: 0.52, 0.60)
- Bottom Line: universal use of NIRUDAK models would:
  - Detect an additional **142,500-171,000** patients per year with severe dehydration that WHO IMAI would miss
  - Prevent overtreatment of **627–912 million** patients per year without any dehydration

A comparison of the NIRUDAK models and WHO algorithm for dehydration assessment in older children and adults with acute diarrhoea: a prospective, observational study

Adam C Levine, Monique Gainey, Kexin Qu, Sabiha Nasrin, Mohsena Bint-E Sharif, Syada S Noor, Meagan A Barry, Stephanie C Garbern, Christopher H Schmid, Rochelle K Rosen, Eric J Nelson, Nur H Alam

Summary

Background Despite the importance of accurate and rapid assessment of hydration status in patients with acute diarrhoea, no validated tools exist to help clinicians assess dehydration severity in older children and adults. The aim of this study is to validate a clinical decision support tool (CDST) and a simplified score for dehydration severity in older children and adults with acute diarrhoea (both developed during the NIRUDAK study) and compare their accuracy and reliability with current WHO guidelines.

Methods A random sample of patients aged 5 years or older presenting with diarrhoea to the icddr,b Dhaka Hospital in Bangladesh between Jan 30 and Dec 13, 2022, were included in this prospective cohort study. Patients with fewer than three loose stools per day, more than 7 days of symptoms, previous enrolment in the study, or a diagnosis other than acute gastroenteritis were excluded. Patients were weighed on arrival and assessed separately by two nurses using both our novel clinical tools and WHO guidelines. Patients were weighed every 4 h to determine their percent weight change with rehydration, our criterion standard for dehydration. Accuracy for the diagnosis of dehydration category (none, some, or severe) was assessed using the ordinal c-index (ORC). Reliability was assessed by comparing the prediction of severe dehydration from each nurse's independent assessment using the intraclass correlation coefficient (ICC).

Findings 1580 patients were included in our primary analysis, of whom 921 (58·3%) were female and 659 (41·7%) male. The ORC was 0·74 (95% CI 0·71–0·77) for the CDST, 0·75 (0·71–0·78) for the simplified score, and 0·64 (0·61–0·67) for the WHO guidelines. The ICC was 0·98 (95% CI 0·97–0·98) for the CDST, 0·94 (0·93–0·95) for the simplified score, and 0·56 (0·52–0·60) for the WHO guidelines.

Interpretation Use of our CDST or simplified score by clinicians could reduce undertreatment and overtreatment of older children and adults with acute diarrhoea, potentially reducing morbidity and mortality for this common disease.

Funding US National Institutes of Health.

Lancet Glob Health 2023

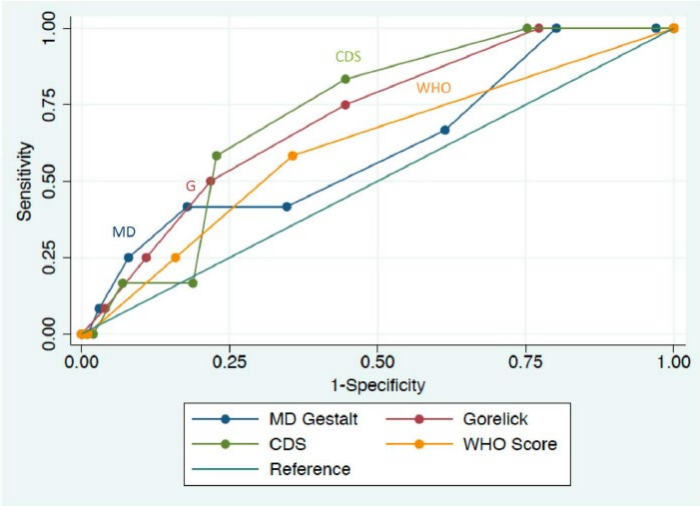
For the Bangla translation of the abstract see Online for appendix 1

Department of Emergency Medicine, Warren Alpert Medical School, Brown University, Providence, RI, USA (Prof A C Levine MD MPH, M A Barry MD, S C Garbern MD); **Department of Emergency Medicine, Rhode Island Hospital, Providence, RI, USA** (M Gainey MS MPH); **Department of Biostatistics** (Prof C H Schmid PhD, K Qu MS) **and Department of Behavioral and Social Sciences** (R K Rosen PhD), **School of Public Health, Brown University, Providence, RI, USA; Nutrition and Clinical Services Division, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b), Dhaka, Bangladesh** (S Nasrin MBBS, M B-E Sharif MBBS, S S Noor MBBS, N H Alam MD); **Departments of Pediatrics and Environmental and Global Health, Emerging Pathogens Institute, University of Florida, Gainesville, FL, USA** (E J Nelson MD PhD)


Questions?

United States

- 113 children under 18 years presenting to single pediatric ED; 10% had moderate (>6%) dehydration by gold standard
- WHO IMCI was **not** a significant predictor of moderate dehydration
- CDS performed better, with significant AUC of 0.72 for predicting moderate dehydration



Technique (Cut Point)*	AUC (95% CI)
CDS (2)	0.72 (0.60, 0.84)
Gorelick (2)	0.71 (0.57, 0.85)
WHO (2)	0.61 (0.45, 0.77)
Physician Gestalt (5)	0.61 (0.44, 0.78)

Jauregui J, et al. External validation and comparison of three pediatric clinical dehydration scales. PLoS One. 2014 May 2;9(5):e95739.

Table 1: DHAKA Derivation

	Included in final analysis (n=771)	Excluded, lost weight (n=16)	Excluded, no final weight (n=63)	p-value
Age in months, median (IQR)	15 (9-29)	18 (13-29)	22 (12-36)	0·07*
Gender				0·84†
Female, n (%)	336 (44)	6 (38)	26 (41)	
Male, n (%)	435 (56)	10 (62)	37 (59)	
Home district				0·99†
Urban (Dhaka), n (%)	478 (62)	14 (88)	45 (71)	
Rural/Suburban, n (%)	293 (38)	2 (12)	18 (29)	
Nutritional status (MUAC)				0·30†
No acute malnutrition, n (%)	614 (80)	16 (100)	53 (84)	
Moderate acute malnutrition (MAM), n (%)	121 (16)	0 (0)	7 (11)	
Severe acute malnutrition (SAM), n (%)	35 (4)	0 (0)	3 (5)	
Days of diarrhea prior to arrival, median (IQR)	2 (1-4)	2 (1·5-3·5)	2 (1-3)	0·13*
Loose stools in past 24 hours, median (IQR)	15 (10-20)	15 (11-20)	15 (10-20)	0·79*
Diarrhea type				0·69†
Watery, n (%)	448 (58)	12 (75)	36 (57)	
Rice-Water, n (%)	317 (41)	4 (25)	27 (43)	
Bloody, n (%)	4 (1)	0 (0)	0 (0)	

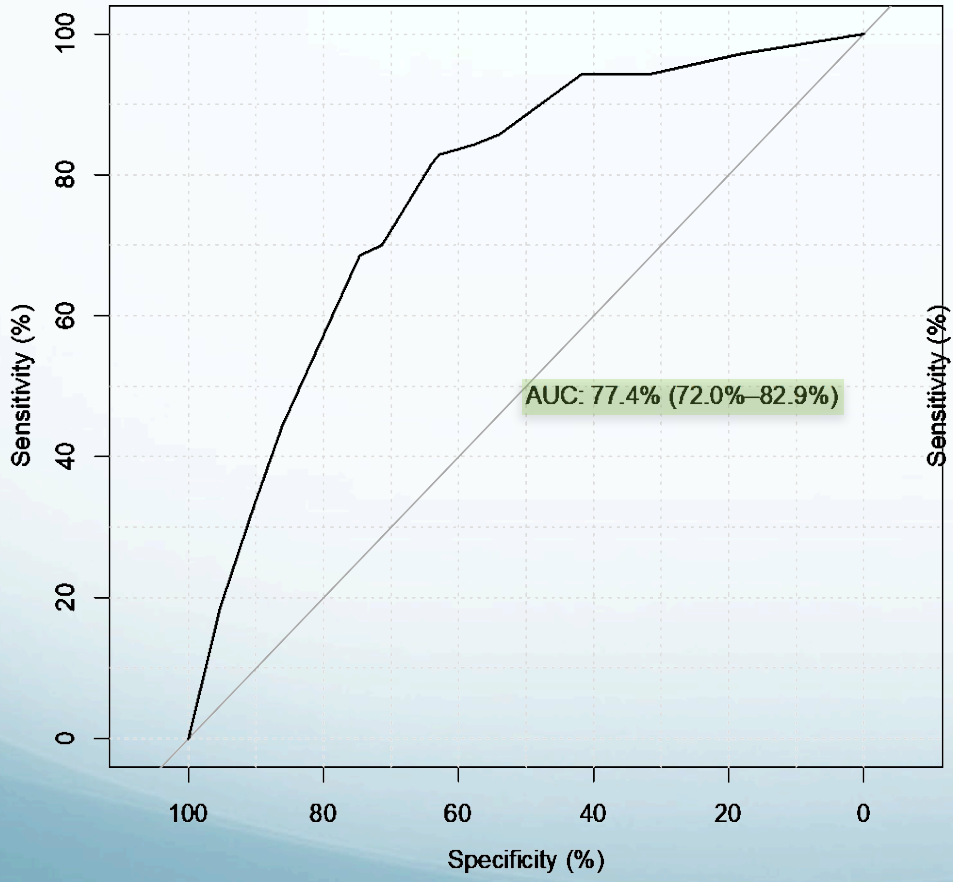
*Equality of Medians †Chi Square

Table 1: DHAKA Validation

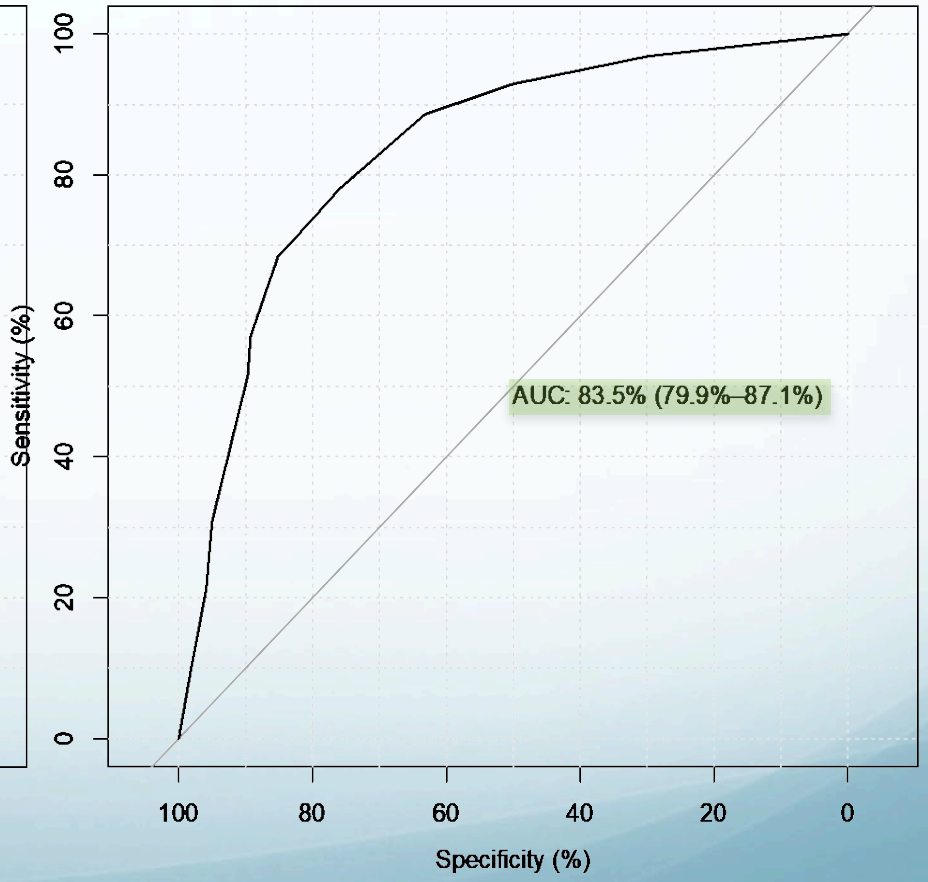
	Included in final analysis (n=496)	Excluded, no final weight (n=50)	P value
Age in months, median (IQR)	16 (9–30)	28 (15–42)	0.001
Sex			0.263
Female, No. (%)	217 (44)	26 (52)	
Male, No. (%)	279 (56)	24 (48)	
Home district			0.348
Urban (Dhaka), No. (%)	356 (72)	39 (78)	
Rural/suburban, No. (%)	140 (28)	11 (22)	
Nutritional status (MUAC)			0.517
No acute malnutrition, No. (%)	391 (79)	40 (80)	
Moderate acute malnutrition (MAM), No. (%)	77 (15)	9 (18)	
Severe acute malnutrition (SAM), No. (%)	28 (6)	1 (2)	
Days of diarrhea prior to arrival, median (IQR)	2 (2–3)	2 (1–3)	0.144
Loose stools in past 24 hours, median (IQR)	10 (8–18)	12 (7–15)	0.451
Diarrhea type			0.227
Watery, No. (%)	368 (74)	32 (64)	
Rice-water, No. (%)	125 (25)	18 (36)	
Bloody, No. (%)	3 (1)	0 (0)	

Accuracy of DHAKA Score

Severe Dehydration



Some Dehydration



Levine AC, et al. External validation of the DHAKA score and comparison with the current IMCI algorithm for the assessment of dehydration in children with diarrhoea: a prospective cohort study. Lancet Glob Health. 2016

Clinical Predictors

	Sensitivity	Specificity	PPV	NPV	LR+ (95% CI)	LR− (95% CI)	Reliability
General Appearance							0.95
Restless/irritable	0.81	0.67	0.72	0.77	2.4 (2.0, 2.9)	0.28 (0.21, 0.37)	
Lethargic/unconscious	0.73	0.69	0.28	0.94	2.3 (1.9, 2.9)	0.39 (0.27, 0.58)	
Skin Pinch							0.85
Slow	0.84	0.68	0.73	0.80	2.6 (2.2, 3.2)	0.23 (0.17, 0.31)	
Very slow	0.40	0.88	0.35	0.90	3.3 (2.2, 4.8)	0.68 (0.56, 0.83)	
Tears							0.63
Decreased	0.83	0.47	0.62	0.73	1.6 (1.4, 1.8)	0.36 (0.27, 0.49)	
Absent	0.29	0.90	0.32	0.88	2.8 (1.8, 4.5)	0.79 (0.68, 0.92)	
Respirations							0.77
Normal	0.67	0.81	0.79	0.70	3.5 (2.7, 4.6)	0.41 (0.34, 0.49)	
Deep	0.36	0.92	0.41	0.90	4.2 (2.7, 6.6)	0.70 (0.59, 0.84)	
Eyes							0.67
Sunken Eyes	0.95	0.26	0.57	0.83	1.3 (1.2, 1.4)	0.20 (0.11, 0.35)	
Sunken Eyes	0.59	0.82	0.34	0.92	3.2 (2.4, 4.2)	0.51 (0.38, 0.67)	
Thirst							0.19
Drinks eagerly, thirsty	0.93	0.21	0.55	0.74	1.2 (1.1, 1.3)	0.34 (0.20, 0.56)	
Not able to drink or drinking poorly	0.13	0.96	0.36	0.87	3.4 (1.6, 7.4)	0.91 (0.83, 0.99)	

DHAKA Subgroup Analysis by Diarrhea Type

	ROC AUC (95% confidence interval)	*P* value χ^2
DHAKA score	–	0.195
Watery diarrhea	0.803 (0.773–0.834)	–
Rice water diarrhea	0.766 (0.720–0.813)	–
IMCI algorithm	–	0.057
Watery diarrhea	0.733 (0.704–0.763)	–
Rice water diarrhea	0.681 (0.636–0.726)	–
CDS	–	0.032
Watery diarrhea	0.784 (0.753–0.815)	–
Rice water diarrhea	0.721 (0.672–0.770)	–

Skrable K, et al. The Effects of Malnutrition and Diarrhea Type on the Accuracy of Clinical Signs of Dehydration in Children under Five: A Prospective Cohort Study in Bangladesh. Am J Trop Med Hyg. 2017 Nov;97(5):1345-1354.

Derivation

	Overall (N = 2139)	Children (N = 630)	Adults (N = 748)	Elderly (N = 761)
Sociodemographic Variables[a]				
Age (years), median (IQR)	35.0(18.0–60.0)	14.0(10.0–17.0)	30.0(25.0–40.0)	62.0(60.0–66.0)
Sex, No. (%)				
Female	1063(49.7)	256(40.6)	409(54.7)	498(52.3)
Male	1095(50.4)	381(59.6)	347(45.5)	367(47.6)
Home location, No. (%)				
Urban	1628(76.1)	507(80.5)	586(78.3)	535(70.3)
Rural/Suburban	511(23.9)	123(19.5)	162(21.7)	226(29.7)
Years of education,[b] median (IQR)	3.0(0.0–7.0)	5.0(2.0–7.0)	5.0(2.0–9.0)	0.0(0.0–4.0)
Monthly household income (USD), median (IQR)	168.0 (120.0–240.0)	144.0 (120.0–204.0)	168.0 (120.0–240.0)	180.0 (120.0–240.0)
People living in household, median (IQR)	5.0(4.0–6.0)	5.0(4.0–6.0)	4.0(3.0–6.0)	5.0(4.0–6.0)
Clinical Variables				
Nutritional status (MUAC), No. (%)				
Severe wasting	31(1.4)	20(3.2)	3(0.4)	8(1.1)
Moderate wasting	164(7.7)	96(15.2)	21(2.8)	47(6.2)
No wasting	1944(90.9)	514(81.6)	724(96.8)	706(92.8)
Enteric Pathogen, No. (%)[c]				
E. coli	834(39.0)	249(39.5)	289(38.6)	296(38.9)
ETEC	212(9.9)	52(8.3)	80(10.7)	80(10.5)
EPEC	5(0.2)	1(0.2)	2(0.3)	2(0.3)
EHEC	0	0	0	0
EIEC	36(1.7)	19(3.0)	6(0.8)	11(1.4)
EAEC	609(28.5)	188(29.8)	209(27.9)	212(27.9)
Vibrio cholera	632(29.5)	260(41.2)	187(25.0)	185(24.3)
Aeromonas	396(18.5)	98(15.6)	160(21.4)	138(18.1)
Campylobacter	219(10.2)	121(19.2)	62(8.3)	36(4.7)
Salmonella	59(2.8)	8(1.3)	26(3.5)	25(3.3)
Shigella	42(2.0)	20(3.2)	7(0.9)	15(2.0)
Other Bacteria[d]	14(0.7)	3(0.5)	7(0.9)	4(0.5)
No Bacteria Detected	620(29.0)	145(23.0)	224(29.9)	251(33.0)
Outcome				
Dehydration category, No. (%)[e]				
Severe dehydration	277(12.9)	100(15.9)	91(12.2)	86(11.3)
Some dehydration	1431(66.9)	432(68.6)	502(67.1)	497(65.3)
No dehydration	431(20.1)	98(15.6)	155(20.7)	178(23.4)

Table 1: NIRUDAK Validation

Sociodemographic variables	
Age, years	
5–10	10 (0·6%)
11–20	358 (22·7%)
21–30	563 (35·6%)
31–40	351 (22·2%)
41–50	176 (11·1%)
51–60	89 (5·6%)
>60	33 (2·1%)
Sex	
Female	921 (58·3%)
Male	659 (41·7%)
Pregnancy status*	
Yes	21 (1·3%)
No	900 (57·0%)
Not applicable	659 (41·7%)
Monthly household income, US$	
First quintile: 0–92·47	441 (27·9%)
Second quintile: 92·48–138·71	497 (31·5%)
Third quintile: 138·72–147·96	40 (2·5%)
Fourth quintile: 147·97–184·94	303 (19·2%)
Fifth quintile: 184·95–924·72	299 (18·9%)
Years of patient education†	5·0 (2·0–9·0)
Home location	
Urban	1159 (73·4%)
Rural or suburban	421 (26·6%)
Time between arrival and final weighing	18 h 9 min (17 h 7 min)

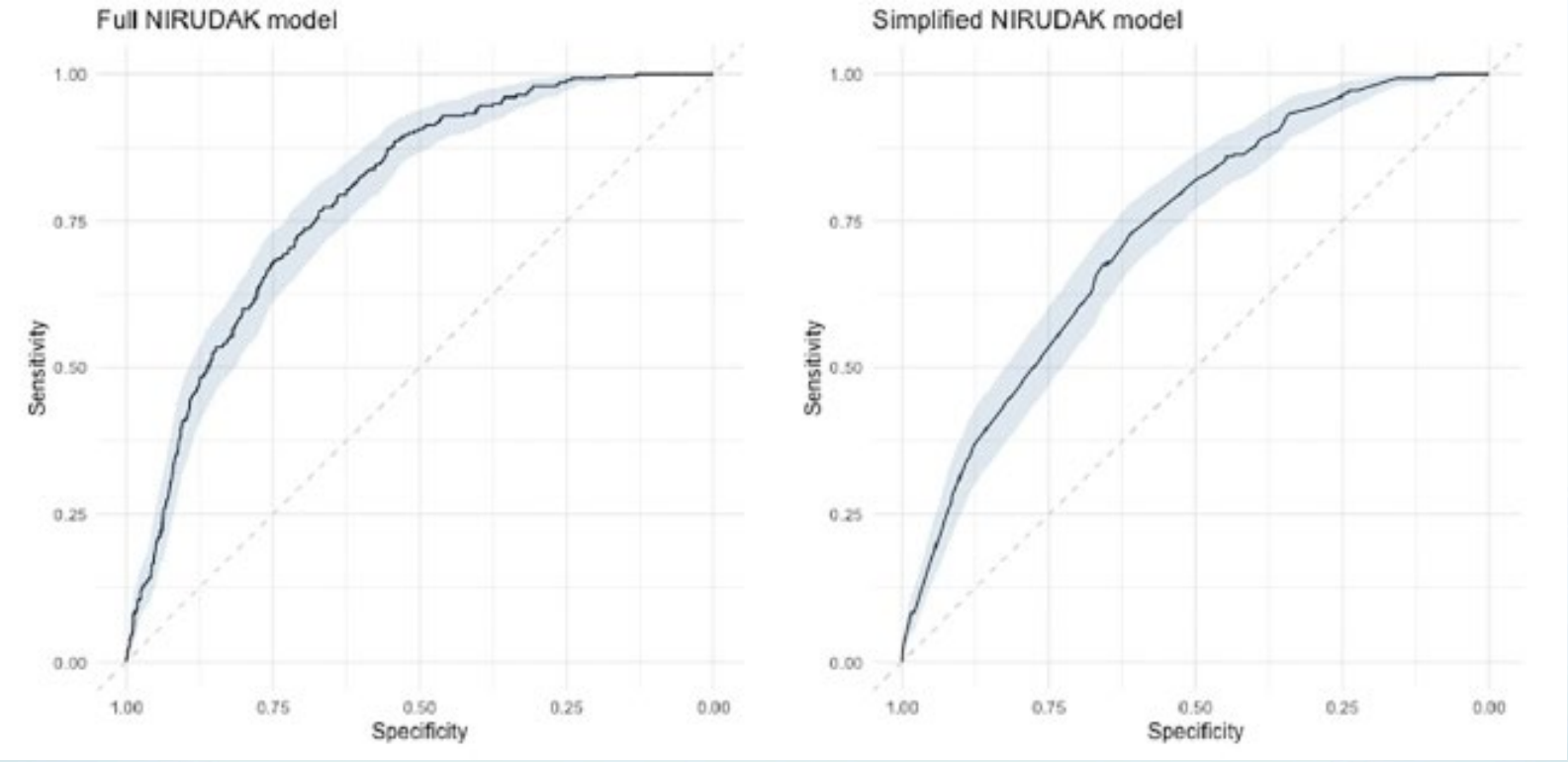
Clinical variables	
Nutritional status (MUAC)‡	
Severe acute malnutrition	10 (0·63%)
Moderate acute malnutrition	160 (10·1%)
No acute malnutrition	1410 (89·2%)
Hours of diarrhoea	14 (10·0–24·0)
Episodes of diarrhea	22·9 (9·2)
Presence of watery stool§	1443 (91·3%)
Presence of bloody stool	6 (0·4%)
Outcome¶	
Dehydration category	
Severe dehydration	120 (7·6%)
Some dehydration	1159 (73·4%)
No dehydration	301 (19·1%)
Fluid deficit, L	2·64 (1·5)

Clinical Predictors

	Sens	Spec	LR Positive	LR Negative	X^2	p-value	K
Skin pinch*†‡							0·98
Slow (AD)	0·68	0·49	1·34	0·65	69·40	<0·001	
Very Slow (SD)	0·55	0·79	2·67	0·57	81·23	<0·001	
Eye level*†‡							0·94
Sunken (AD)	0·93	0·19	1·14	0·40	35·76	<0·001	
Sunken (SD)	0·98	0·10	1·09	0·24	6·98	0·008	
Vomiting episodes*							0·97
> 0 episodes (AD)	0·88	0·17	1·06	0·70	17·92	<0·001	
> 9 episodes (SD)	0·63	0·45	1·15	0·82	3·79	0·29	
Respiration Depth*†							0·98
Deep (AD)	0·39	0·84	2·41	0·73	56·86	<0·001	
Deep (SD)	0·62	0·68	1·93	0·56	42·31	<0·001	
Radial Pulse†							0·74
Decreased (AD)	0·85	0·35	1·31	0·42	63·82	<0·001	
Absent (SD)	0·23	0·88	1·94	0·87	21·10	<0·001	
Urine Output†							0·91
Decreased/Dark (AD)	0·83	0·25	1·12	0·66	24·19	<0·001	
Minimal/None (SD)	0·41	0·74	1·54	0·81	11·40	0·003	
Mental Status‡							0·96
Lethargic/Unconscious (AD)	0·20	0·88	1·65	0·91	9·96	0·002	
Lethargic/Unconscious (SD)	0·44	0·84	2·68	0·67	54·20	<0·001	
Thirst‡							0·38
Drinks Eagerly (AD)	0·97	0·09	1·07	0·36	13·30	0·001	
Refuses/Unable to Drink (SD)	0·56	0·60	1·38	0·74	11·52	0·003	

*Clinical sign included in the Full NIRUDAK model
†Clinical sign included in Simplified NIRUDAK model
‡Clinical sign included in WHO IMAI algorithm

Accuracy of NIRUDAK Models for Severe Dehydration

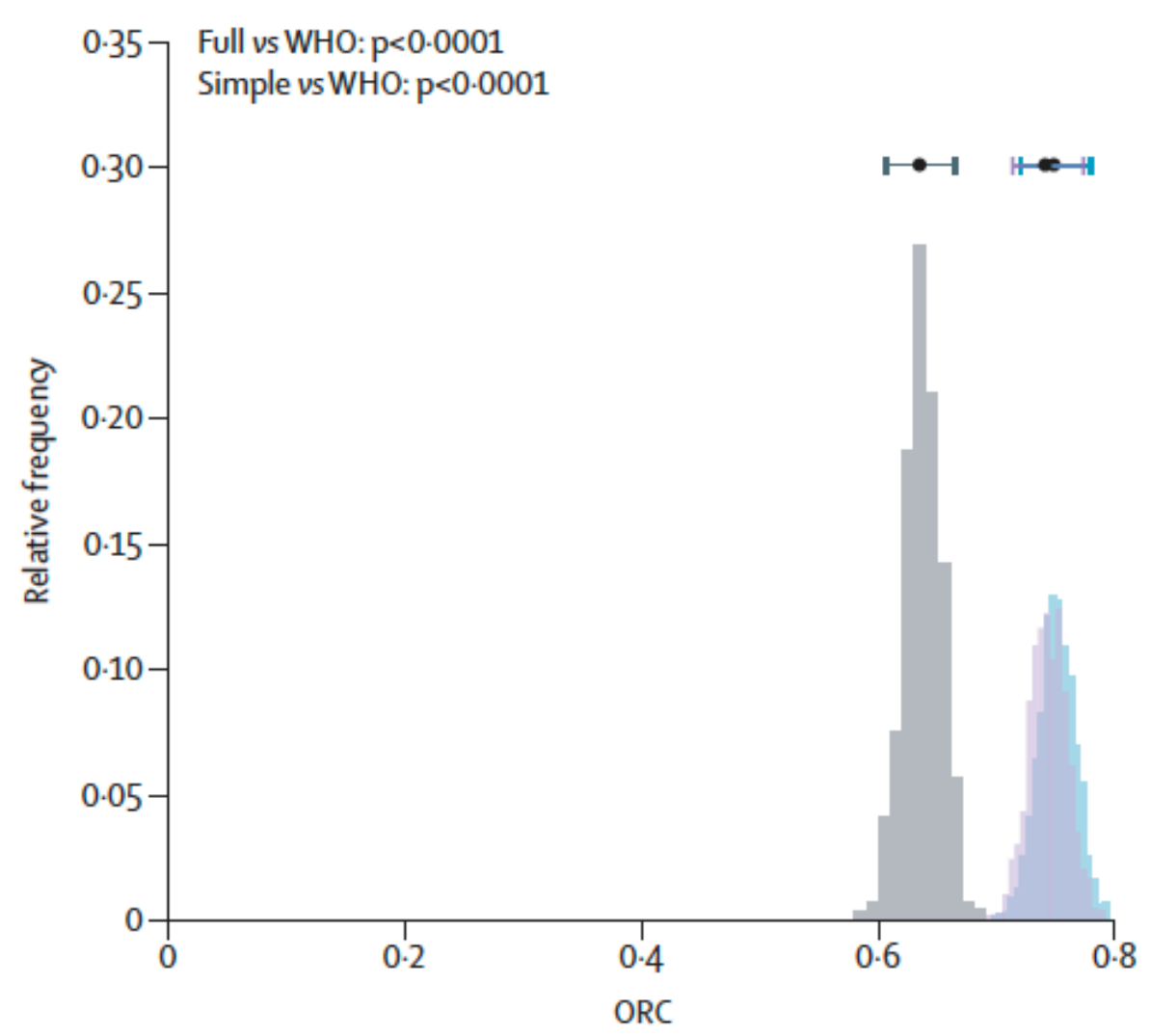


AUC = 0.79 (95% CI: 0.76-0.82)

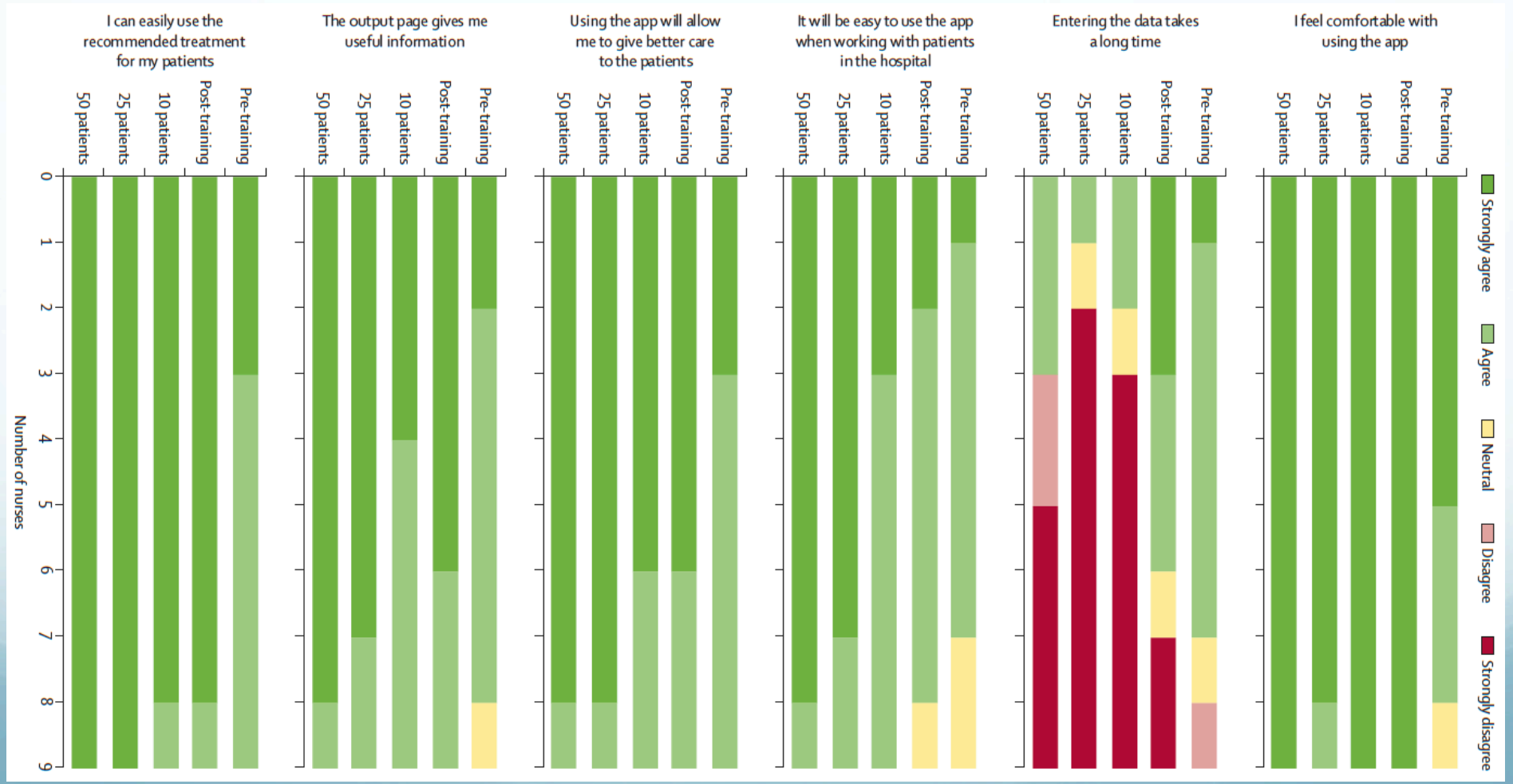
AUC = 0.73 (95% CI: 0.70-0.76)

Levine AC, et al. Derivation of the First Clinical Diagnostic Models for Dehydration Severity in Patients over Five Years with Acute Diarrhea. PLoS Negl Trop Dis. 2021 Mar 10;15(3):e0009266.

NIRUDAK Outperforms WHO

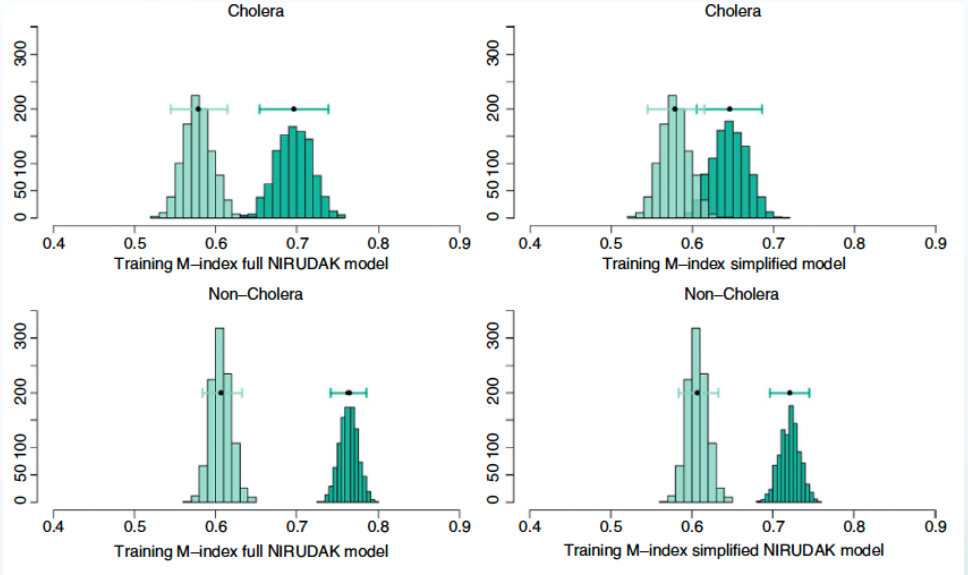


NIRUDAK Usability



NIRUDAK Subgroup Analysis

	Training Set M-Index	Validated M-Index (95% Confidence Interval)
NIRUDAK Full Model		
Cholera	0.70	0.70 (0.65, 0.74)
Non-Cholera	0.76	0.76 (0.74, 0.79)
NIRUDAK Simplified Model		
Cholera	0.67	0.68 (0.65, 0.73)
Non-Cholera	0.72	0.72 (0.70, 0.74)
WHO Model		
Cholera	0.58	0.58 (0.54, 0.61)
Non-Cholera	0.61	0.61 (0.58, 0.63)



p<0.001 for all comparisons

Gainey M, et al. Assessing the Performance of Clinical Diagnostic Models for Dehydration among Patients with Cholera and Undernutrition in Bangladesh. Tropical Medicine and International Health, 2021; 00: 1-14.