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Provider Knowledge Performance After Initial "Saving Children's Lives" Training in Botswana

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Abbreviations: serious childhood illness (SCI), Saving Children's Lives (SCL), abbreviated high intensity training (aHIT), Integrated Management of Childhood Illness (IMCI), World Health Organization (WHO), low and middle-income countries (LMICs), international faculty (IF), local faculty (LF), international faculty only (IFO), < 70% local faculty (LT70LF), > 70% local faculty (GT70LF), local faculty only (LFO)

Table of Contents Summary:
Saving Children's Lives training significantly increases healthcare provider knowledge to care for seriously ill children and is highly relevant to middle-income country health systems.

Contributors' Statement:
Dr Meaney conceptualized and designed the study, carried out the initial analyses, designed the data collection instruments, drafted the initial manuscript, and critically reviewed the manuscript for important intellectual content.
Mr Setlhare designed the data collection instruments, collected data, carried out the initial analyses, and critically reviewed the manuscript for important intellectual content.
Dr Joyce collected data, carried out the initial analyses, and critically reviewed the manuscript for important intellectual content.
Mrs Kgosiesiele, Dr Kalenga and Jibril conceptualized and designed the study, coordinated and supervised data collection.
Dr Kloeck coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content.
Drs Mensinger, Zhang, and Smith made substantial contributions to analysis and interpretation of data, and critically reviewed the manuscript for important intellectual content.
Dr Mazhani, deCaen and Steenhoff conceptualized and designed the study, and critically reviewed the manuscript for important intellectual content.
All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Data Sharing Statement: copy of the dataset is available by emailing the corresponding author (meaneypa@stanford.edu)

Abstract

Objectives

Millions of children die every year from serious childhood illnesses. Most deaths are avertable with access to quality care. Saving Children's Lives (SCL) includes an abbreviated high intensity training (SCL-aHIT) for providers who treat serious childhood illnesses. The objective of this study was to examine the impact of SCL-aHIT on knowledge acquisition and retention of providers.

Setting:

76 participating centers who provide primary and secondary care in Kweneng District, Botswana.

Participants:

499 providers trained between January 2014 and December 2016. 211 had data available for analysis. Providers who were expected to provide initial stabilizing care to seriously ill children, had completed SCL-aHIT, submitted demographic data, course characteristics, and at least one knowledge assessment were eligible for inclusion.

Methods:

Retrospective, cohort study. Planned and actual primary outcome was adjusted acquisition (change in total knowledge score immediately after training) and retention (change in score at 1, 3 and 6 months), secondary outcomes were pneumonia and dehydration sub scores. Descriptive statistics and linear mixed models with random intercept and slope were conducted. Relevant IRBs approved this study.

Results:

Cohort was 91% nurses, 71% clinic/health-post based, and 45% pre-trained in Integrated Management of Childhood Illness (IMCI). A strong effect of SCL-aHIT was seen with knowledge acquisition (+26.01±2.24, p <0.0001), and retention out to 6 months (-0.34±0.59/month, p=0.566). IMCI training demonstrated no significant effect on acquisition (+5.83±3.24, p=0.07 or retention (+0.08±0.8/month, p=0.920) of knowledge. Overall, nurses scored lower than physicians (-19.71±4.61, p <.0001). Lost to follow-up had a significant impact on knowledge retention (-2.47 points/month± 0.7, p 0.0015).

Conclusions:

Abbreviated high intensity training for care of the seriously ill child significantly increased provider knowledge and it was sustained out to 6 months. IMCI training did not significantly impact overall knowledge acquisition nor retention, while professional status impacted acquisition and loss to follow-up impacted retention.

Strengths and limitations of this study

- This study demonstrated an abbreviated high-intensity training on the seriously ill child significantly increases provider knowledge and was sustained at six months. Abbreviated high intensity training may significantly improve quality of care.
- Participants with previous IMCI training did not have decreased knowledge acquisition or improved retention compared to those without IMCI training, highlighting the non-redundant training of SCL and IMCI
- Nurses and those lost to follow-up had poorer acquisition and retention scores, respectively. This may represent need to adapt SCL-aHIT to more optimal learning styles of different providers or increase training opportunities in preclinical training.
- Limitations are that outcomes are limited to knowledge of provider, not actual or reported performance

What do the new findings imply?

Focused high intensity training on the seriously ill children is added value to IMCI training and may improve quality of care in low- and middle-income countries.

Introduction

Each year, severe pneumonia, shock from diarrheal dehydration and sepsis are responsible for 25% of 5.1 million child deaths that occur worldwide.[1,2] Over 1 million children die each year due to lack of effective, low-cost interventions being available and utilized appropriately.[3] Access to quality healthcare is a global challenge, and timely and effective treatment for pneumonia and diarrhea are essential components.[4-6]

A child mortality audit in Botswana between 2011-2013 demonstrated that 46% of pediatric in-hospital deaths were due to severe pneumonia, diarrheal dehydration and sepsis.[7] 33% of in-hospital pediatric deaths occurred within the first 24 hours, an indication that children arrived critically ill. 26% of all in-hospital deaths were considered avoidable, with an average of 2.6 modifiable factors contributing to each death.[7] Delayed or inadequate recognition and treatment of serious illness were major modifiable factors, and over 50% of factors were attributed to provider performance.

Healthcare providers in Botswana are trained to care for ill children using the Integrated Management of Childhood Illness (IMCI). IMCI is a training program endorsed by the World Health Organization (WHO) to train healthcare providers to care for children in low and middle-income countries (LMICs). However, studies have demonstrated that after health providers receive IMCI training, one-third to one half of seriously ill children are not identified and do not receive correct treatment for potentially life-threatening conditions.[8-10]

Saving Children's Lives (SCL) is a novel, multi-intervention implementation strategy of evidence-based practices to improve the quality of care for seriously ill or injured children at first-level facilities in Botswana. It is a collaboration between the Botswana Ministry of Health, the University of Botswana, Botswana University of Pennsylvania Partnership, Children's Hospital of Philadelphia Center for Global Pediatric Critical Care, and the American Heart

Association. Initial training in the Saving Children's Lives program is a novel abbreviated high-intensity training (aHIT) program focused on the knowledge and skills a healthcare provider needs to optimally recognize and initiate stabilizing treatment in the community clinic, primary or district hospital setting. The contextualization process and initial training program has been described previously.[11]

We hypothesized that SCL-aHIT would lead to significant knowledge acquisition and retention by healthcare providers who work at first-level facilities. We also hypothesized that IMCI training would not have significant impact on knowledge acquisition or retention. Further, we hypothesized that provider, training or work environment characteristics may impact knowledge acquisition and retention.

Methods:

Setting:

Kweneng District, Botswana, has a population of 304,000, with 83% people living within 8 km of a health facility (100% within 15km).[12-14] There is one district hospital, two primary hospitals, nine clinics with beds, and sixty-four health posts and clinics without beds in the district. The estimated doctor/population ratio is 1:550 and nurse/population ratio of 1:80.

Cohort Description:

Cohort consisted of a convenience sample of providers from community clinics, health posts, primary and district hospitals. Providers were identified for training by the Kweneng District Health Management team based on if they were expected to provide initial stabilizing care to seriously ill children in their position. To minimize selection bias, all providers identified in Kweneng district completed training and follow-up assessments were attempted. All subjects who participated in SCL-aHIT, completed demographic data and at least one knowledge assessment were eligible for inclusion. Providers included physicians and nurses.

Abbreviated High Intensity Training:

Rowe et al defined high intensity training as having a duration > 5 days which included interactive sessions (e.g. role play).[15] We defined abbreviated high intensity training (aHIT) as having interactive sessions but with a training duration < 5 days. The initial SCL training is a contextualized, 2-day version of the American Heart Association's Pediatric Emergency Assessment Recognition and Stabilization program.

Study design:

This retrospective cohort study was conducted to examine the impact of district-level SCL-aHIT on provider knowledge in Kweneng District, Botswana. Data extracted from the SCL administrative database included participant demographics and knowledge assessments. Our primary outcome was total score acquisition with secondary outcomes of total score retention, and pneumonia and diarrhea subscores of both acquisition and retention. Knowledge assessments were conducted prior to training (baseline), immediately following training (post), and at 1, 3, and 6 months after training. Individual feedback on assessment performance was given immediately by a SCL coordinator at all time-points except pre-course. Scores were treated as continuous variables (potential range from 0-100) based on the SCL knowledge assessment. The knowledge assessment is a 6-item multiple-choice questionnaire targeted to basic content regarding recognition and treatment of severe dehydration and moderate-severe pneumonia. Question types include 'select all that apply' and single best answer. Correct volume and rate of fluid administration for severe dehydration were consistent with current WHO and PALS guidelines. Choice of antibiotics for pneumonia was dependent on reported location of work and aligned with national guidelines. Student characteristics were self-reported based on registration and included: professional status, work location, type of personal mobile phone (smart vs other), language most commonly spoken, IMCI subtypes (time since training, training duration - short vs long), other previous resuscitation training, perception of resuscitation, and course multiple choice question (MCQ) score. A smart phone was defined as a mobile phone that had applications, access to internet and email. Training characteristics included year of training and instructor mix. We defined the instructor mix of the initial training to be of four types: international faculty only (IFO), < 70% local faculty (LT70LF), > 70% local faculty (GT70LF), and local faculty only (LFO). We also defined training by the year initial SCL training was conducted: Jan 1-Dec 31 for 2014 (IF led, full program support), 2015 (LF led, high degree of IF supervision, full program support), and 2016 (LF led, minimal IF supervision, minimal program support).

Statistical Approach:

The statistical analysis was performed using SAS software, version 9.4. Means and standard deviations were presented for continuous variables, while frequency and percent were presented for discrete variables. Difference in baseline participant or course characteristics between IMCI and non-IMCI groups, and difference in immediate post-training assessment score among groups were tested with two-sample t-test or one-way ANOVA for continuous variables, and Chi-square test or Fisher's exact test for discrete variables, as appropriate.

To assess the trend of participants' knowledge level over the study period, we used linear mixed models with random intercept and slope to adjust for repeated measurements for each participant.

A piece-wise segmented regression approach was used to model time, with baseline to immediate post-training as the first segment (knowledge acquisition), and immediate post-training to 6-month follow-up as the second segment (knowledge retention). Previous IMCI training was added as a primary predictor in the model to assess the difference in baseline knowledge level between the IMCI versus non-IMCI group. An interaction effect between previous IMCI training and the piece-wise time effects was also added into the model to assess whether IMCI training enhanced or diminished knowledge acquisition and/or retention. As for covariates, we included year of training in the model, a priori. Any participant or course variable that was significantly different (at alpha = 0.10) between IMCI and non-IMCI participants or had significantly different course assessment scores in bivariate analysis was included in the linear mixed model. In addition, time required to conduct follow-up assessments by phone or in person was limited and prohibited follow-up of all subjects at all time points. Nevertheless, to check for non-random loss of follow-up (non-response bias), we conducted a sensitivity analysis. Normality of outcome variables were assessed using histogram and Kolmogorov-Smirnov test. Linearity of trend in each time segment was assessed using the plot of mean score by time and IMCI. Multicollinearity was assessed using both Pearson Correlation Coefficient ($r<0.8$) and variance inflation factor ($vif<10$) with course-assessment values.

Ethics/IRB Considerations, Patient and Public Involvement:

We used the STROBE cohort checklist when writing our report.[16] The study was approved by ethics boards of the Botswana Ministry of Health and the University of Pennsylvania. Patients and the public were not involved.

Results:

Description of cohort

Between January 2014 and December 2016, 499 providers were trained, and 211 providers had data for analysis. 91% (187) were nurses, and of the 179 reporting their work location, 71% (127) were clinic/health post based and 29% (52) hospital based (Table 1). 98% (207) of providers had a mobile phone and 53% (111) reported owning a smart phone. 24% reported English was the most commonly used language. 67% self-reported that they resuscitated a seriously ill child at least once a month, and 30% and 20% of participants were not comfortable with the initial steps of stabilizing a child with severe pneumonia or diarrhea, respectively. 41% (84) of providers perceived resuscitation to be successful in less than 25% of cases where they work. Only 45% (95) reported previous IMCI training. Of providers with previous IMCI training, 74% (70) reported that the duration of IMCI training was less than 7 days (Table 2). 38 (40%) received IMCI training > 5 years ago and 32 (34%) < 2 years ago. Pediatric, neonatal or trauma resuscitation training was less than 12%, while 35% (73) had received CPR training. 78% (162) of participants received training in 2014, while 29% (60) were taught by an instructor group with 70% local instructors or only local instructors.

Sensitivity Analysis

To determine whether there were biases due to loss to follow-up, we created two groups: one group that had 6-month follow-up score and one group that did not have 6-month follow-up. We compared the acquisition of knowledge trajectory and retention of knowledge trajectory to ensure they were similar. Analysis showed differences in knowledge retention between the groups: the group with 6-month follow-up did not have a significantly better knowledge acquisition (+4.0, se=3.9, p=0.3), but demonstrated significantly better retention (+2.8/month, se=0.9, p=0.002). To control for this bias, we entered this variable into the piecewise regression models. See Supplementary Table and Figures for results of the sensitivity analysis.

Description of Model

Normality was basically satisfied. Linearity was satisfied within each time segment. No multi-collinearity issue was tested. Covariates included in the final model included: year of initial training, professional status, smart phone usage, language spoken most commonly, degree of comfort with treatment of severe pneumonia, location of work, ever previously trained in neonatal resuscitation, perceived frequency of resuscitation, and presence/absence of 6-month follow-up.

A strong and significant main effect was seen for knowledge acquisition due to SCL-aHIT (time: pre to post) (b= +26.01 ±2.24, p<.0001), and there was no significant loss of knowledge over time (b= -0.34 ±0.59/month, p=0.566) (Table 3). The main effect for IMCI training was not significant (b=-1.57 ±2.91, p=0.589). There was no interaction effect between IMCI training and knowledge acquisition (b=+5.83 ±3.24, p=0.073), or between IMCI training and knowledge retention (b=+0.08 ±0.80/month, p=0.920), for total scores.

For dehydration subscores, a strong and significant main effect was seen for both knowledge acquisition (b=+14.26 ±1.46, p <0.001), and loss of knowledge over time (b= -1.01 ±0.38/month, p=0.009). There was no interaction effect between IMCI training and dehydration knowledge acquisition (b= +0.73 ±2.10, p=0.730), or between IMCI training and knowledge retention (b= +0.21 ±0.51/month, p=0.685) for dehydration subscores.

For pneumonia subscores a strong and significant main effect was seen for knowledge acquisition (b= +11.72 ±1.64, p <0.001), and no significant change in knowledge over time (b= +0.59 ±0.38/month, p=0.123). Groups with IMCI training got significant higher knowledge acquisition than those without IMCI training (b= +5.15 ±2.36, p = 0.031) but no significant interaction effect between IMCI training and retention (b= -0.05 ±0.52/month, p=0.930), for pneumonia subscores.

Additionally, on average, nurses scored significantly lower than physicians: (b= -19.71 ±4.61, p <.0001) on total score, (b = -6.16±2.39, p=0.011) on dehydration sub-score, and (b= -12.89±3.68, p=0.0005) on pneumonia sub-score. Compared to those who worked in hospitals, participants who worked in clinics/health posts scored significantly worse on dehydration: (b= -2.97±1.19, p=0.013) and better on pneumonia sub score (b= +6.84±1.83, p=0.0002). There were no differences on total score between participants who work in clinics/health posts and hospitals (b= +3.81±2.30, p=0.100)

In the final model, co-variates of previous neonatal training, perceived frequency of resuscitation, language, perceived comfort with treatment of pneumonia, smart phone usage, year of training and completeness of follow-up had no significant effect on total scores or subscores.

Model-based mean scores for each assessment were calculated based on populations that represented the majority of the cohort: those who had SCL initial training in 2014, were nurses, used smartphones, spoke non-English most commonly, were comfortable treating of severe pneumonia, worked in clinic/health post, had no previous training in neonatal resuscitation, reported frequency of resuscitation >1/month, and did not complete a 6-month assessment (Table 4). Plots were created based on the same values as the model-based means (Figure 1-3).

Discussion:

This study demonstrates for the first time that SCL's abbreviated high intensity training significantly increases provider knowledge acquisition in the recognition and treatment of serious childhood illness. Further, it demonstrated no significant loss of knowledge up to 6 months after initial training. Finally, while previous IMCI training did not decrease knowledge acquisition, professional status and completing follow up assessments impacted scores significantly.

This increase in knowledge may be due to the characteristics of training, and our study is consistent with previous studies that demonstrate high intensity training being the most effective single implementation strategy to improve healthcare worker performance.[15,17] Rowe et al found that high intensity training had the greatest median training effect (11, IQR 8-15) compared to low-intensity training only (8, IQR 2-22), supervision (8, IQR 3-17), group problem solving (8, IQR 6-21), regulation/governance (5, IQR -1-20) or job aids (-3, IQR -7-+7). Further, the high impact of an abbreviated (2-day) high-intensity training is notable as shortened (5-10 day) IMCI training has been associated with a 2 to 16-point loss of treatment effect over standard (11-day) training.[9] While SCL-aHIT demonstrated a larger effect than the range in the systematic review, our outcomes were limited to knowledge assessment and the difference in magnitude needs to be interpreted with caution. Interestingly, nurses scored significantly lower than physicians. This may be due to differences in pre-clinical education, in-service training, or unmeasured provider and environment characteristics that are highly correlated with professional status. Nevertheless, as nurses are the major training target for SCL-aHIT, further modifications to course content, structure or follow-up training may be needed.

Provider knowledge of treating serious childhood illness was sustained up to 6 months after SCL's abbreviated high intensity training. This is significant as previous studies in resuscitation training have demonstrated that knowledge and skills decrease significantly over time, often in as little as in 6-12 weeks after training.[18-22] This has also been seen with clinical management of malaria[23] as well as with IMCI[10]. There are several reasons that may account for this. It may be due to the contextualization process to ensure training was relevant to disease epidemiology and health system resources in Botswana. It may have been due to other components of SCL program besides aHIT. The SCL program integrates support in inventory of relevant medication and functioning equipment as part of its training and it provides immediate individual education on follow-up assessments by a master trainer. The SCL program utilized active reporting of training results to local health leadership – this may have stimulated additional feedback and support through administrative communication independent of the SCL program. Finally, it may be due to regression to the mean, as baseline knowledge scores were low and thus could only improve.

Due to the administrative nature of the database queried, there was significant loss to follow-up which was associated with differential retention and required a variable to control for its effect. This natural experiment allowed us to detect this difference, but it is unclear whether the barrier is innate to the provider, the system they worked or trained in, the subject matter or the interplay of one or more of these characteristics.

In this study, previous IMCI training did not significantly impact provider knowledge gained or retained from SCL-aHIT. A test for an interaction effect between previous IMCI training and baseline to post-training changes showed a marginally significant yet potentially important effect on knowledge acquisition (5.83 ± 3.23, $p=.07$) The fact that knowledge may increase with those with previous IMCI training may point to IMCI being a good general foundation for more focused programs to then build upon where needed. That overall knowledge gained from SCL-aHIT was not negatively impacted supports the theory that programs such as SCL that focus on serious childhood illness may be an added value and not redundant to IMCI training. This may be especially important in environments where quality of pneumonia and diarrhea care is poor despite IMCI implementation. While IMCI-trained workers are more likely to correctly classify illnesses, administer oral therapies, employ rational antibiotic use, vaccinate children, and counsel families on adequate nutrition for moderate illness,[8,24] IMCI has limited impact on care delivery of the seriously ill child.[8-10] If there was significant overlap in content between SCL and IMCI, we might expect higher baseline scores and decreased acquisition. Alternatively, it may be that current existing IMCI training is not optimally effective.

Access to quality treatment of pneumonia and diarrhea are major contributors to avertable mortality worldwide.[4-6] Studies of provider performance show that standard guidelines were only followed 30-40% of the time, and often led to misallocation of resources.[25] Further, studies have shown that children with complex serious illness often receive worse care than those with milder, straightforward presentations.[26,27] This poor quality of services for treatable conditions is directly responsible for over 5 million deaths each year and contributes to decreased utilization of services, which accounts for another 3.6 million deaths.[6] A sustained and integrated improvement of provider knowledge and resource awareness is needed to address these gaps that limit systems to provide quality care. When healthcare providers recognize severely ill children early and stabilize them in the pre-hospital setting, it limits disease progression and requires less costly resources to improve child survival.

Limitations:

As with any study there were several limitations. Use of an administrative database and infrastructure for the SCL program may have contributed to non-random loss to follow-up. Although effect was minimized through the conducted sensitivity analyses (see appendix), the study should be repeated with stronger support for follow-up data collection as well as training. Our outcome data was limited to knowledge assessments, and future studies that examine operational performance or patient outcomes are needed. The knowledge assessments have not been previously validated, and future studies should have multiple versions to better discriminate retention of test knowledge versus content knowledge.

Conclusion:

Abbreviated high intensity training focused on the seriously ill child significantly increases provider knowledge for both clinic and hospital-based providers. Gains in knowledge from SCL-aHIT was sustained up to 6 months. IMCI training did not significantly impact overall knowledge acquisition or retention, but professional status impacted acquisition and loss to follow-up impacted retention of knowledge. In health systems where access to quality care for the seriously ill child is poor, programs such as Saving Children's Lives may have a significant impact.

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Table 1: Provider Characteristics	Overall	ICMI trained	No ICMI	p value
N	211	95	116	
Professional Status*		[n (%)]	[n (%)]	
Nurse	187 (90.8)	91 (48.7)	96 (51.3)	0.0061
Physician	19 (9.2)	3 (15.8)	16 (84.2)	
Location of work				
Clinic or Health post	127 (71.0)	62 (48.8)	65 (51.2)	0.5768
Hospital	52 (29.0)	23 (44.2)	29 (55.8)	
Other	32			
Mobile phone**				
Smart	111 (53.1)	57 (51.4)	54 (48.6)	0.0684
Text and Voice only	98 (46.9)	38 (38.8)	60 (61.2)	
No cell phone	3	0	3	
English spoken most commonly				
Yes	51 (24.2)	15 (29.4)	36 (70.6)	0.0101
No	160 (75.8)	80 (50.0)	80 (50.0)	
Perceived frequency of resuscitation > 1 month				
Yes	138 (66.7)	65 (47.1)	73 (52.9)	0.4896
No	69 (33.3)	29 (42.0)	40 (58.0)	
Missing	4			
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia				
Agree	147 (69.7)	78 (53.1)	69 (46.9)	0.0004
Disagree/Neutral	64 (30.3)	17 (26.6)	47 (73.4)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Dehydration.				
Agree	168 (79.6)	80 (47.6)	88 (52.4)	0.1342
Disagree/Neutral	43 (20.4)	15 (34.9)	28 (65.1)	
Resuscitation Success (perceived)				
0-25%	84 (40.8)	42 (50.0)	42 (50)	0.2832
26-50%	32 (15.5)	13 (40.6)	19 (59.4)	
51-75%	37 (18.0)	12 (32.4)	25 (67.6)	
76-100%	53 (25.7)	26 (49.1)	27 (50.9)	
Previous Resuscitation Training				
Pediatric	23 (11.1)	12 (52.2)	11 (47.8)	0.4
Neonatal	21 (10.2)	8 (38.1)	13 (61.9)	0.55
Trauma	21 (10.2)	7 (33.3)	14 (66.7)	0.2911
CPR	73 (35.1)	29 (39.7)	44 (60.3)	0.3361
Year of the program***				
2014	162 (77.9)	77 (47.5)	85 (52.5)	0.3128
2015 & 2016	46 (22.1)	18 (39.1)	28 (60.9)	

Instructor Type***				
IFO	52 (25.0)	28 (53.9)	24 (46.1)	0.3872
LT70LF	96 (46.2)	44 (45.8)	52 (54.2)	
GT70LF	39 (18.8)	16 (41.0)	23 (59.0)	
LFO	21 (10.0)	7 (33.3)	14 (66.7)	

*5 participants did not report profession
** 2 did not report cellphone access
***3 did not report year of training or instructor type
Previous Pediatric Resuscitation = Pediatric Advanced Life Support, Emergency Triage Assessment and Treatment
Previous Neonatal Resuscitation = Neonatal Resuscitation Training, Helping Babies Breathe.
Previous CPR: Cardiopulmonary Resuscitation
Other includes hospital based (administrative/'other'= 29, not reported/missing = 3)

Table 2: Characteristics of provider previous IMCI training	N=95
Time since training	% (N)
< 6 months	14% (13)
>6months-2years	20% (19)
2-5yr	26% (25
>5 years	40% (38)
IMCI Course Duration	% (N)
< 7 days	74% (70)
≥ 7 days	26% (25)

Table 3: Predictor	Estimate (se)	p
Total Score		
IMCI	-1.57 (2.91)	0.59
Knowledge:		
Acquisition (pre-post)	26.01 (2.24)	<.0001
Retention (per month after course)	-0.34 (0.59)	0.57
Interaction effect of IMCI on:		
Acquisition (pre-post)	5.83 (3.24)	0.07
Retention (per month after course)	0.08 (0.80)	0.91
Dehydration sub score		
IMCI	1.7 (1.71)	0.32
Knowledge:		
Acquisition (pre-post)	14.26 (1.46)	<.0001
Retention (per month after course)	-1.01 (0.38)	0.009
Interaction effect of IMCI on:		
Acquisition (pre-post)	0.73 (2.10)	0.73
Retention (per month after course)	0.21 (0.51)	0.69
Pneumonia sub score		
IMCI intercept	-3.32 (2.34)	0.16
Knowledge:		
Acquisition (pre-post)	11.72 (1.64)	<.0001
Retention (per month after course)	0.59 (0.38)	0.12
Interaction effect of IMCI on:		
Acquisition (pre-post)	5.15 (2.36)	0.03
Retention (per month after course)	-0.05 (0.52)	0.93
Adjusting for: year of initial training, professional status, smart phone usage, language spoken most commonly, and degree of comfort with treatment of severe pneumonia, location of work, ever previously training in neonatal resuscitation, perceived frequency of resuscitation, and completion of knowledge assessments at 6 months follow-up.		

Table 4: Estimated Marginal Means (Model-based Means)		Pre-Course	Post Course	1 month	3 months	6 months
		N=205	N=208	N=129	N=93	N=44
Total Score		Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
	No IMCI	48.2 (2.8)	74.2 (2.6)	73.8 (2.6)	73.2 (2.8)	72.1 (3.9)
	IMCI	46.6 (2.7)	78.4 (2.4)	78.2 (2.3)	77.7 (2.5)	76.9 (3.5)
Dehydration Sub-score						
	No IMCI	14.4 (1.6)	28.6 (1.4)	27.6 (1.4)	25.6 (1.5)	22.6 (2.3)
	IMCI	16.1 (1.5)	31.1 (1.3)	30.3 (1.2)	28.7 (1.4)	26.3 (2.1)
Pneumonia Sub score						
	No IMCI	33.8 (2.3)	45.5 (2.0)	46.1 (2.0)	47.3 (2.2)	49.1 (2.8)
	IMCI	30.5 (2.1)	47.4 (1.8)	47.9 (1.8)	49.0 (1.9)	50.6 (2.5)

Note: Means were calculated based on populations who had SCL initial training in 2014, were nurses, use smartphones, non-English spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment.

Figure 1:

- Caption: Model-Based Marginal Total Score by IMCI Training over Time (adjusted)
- Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

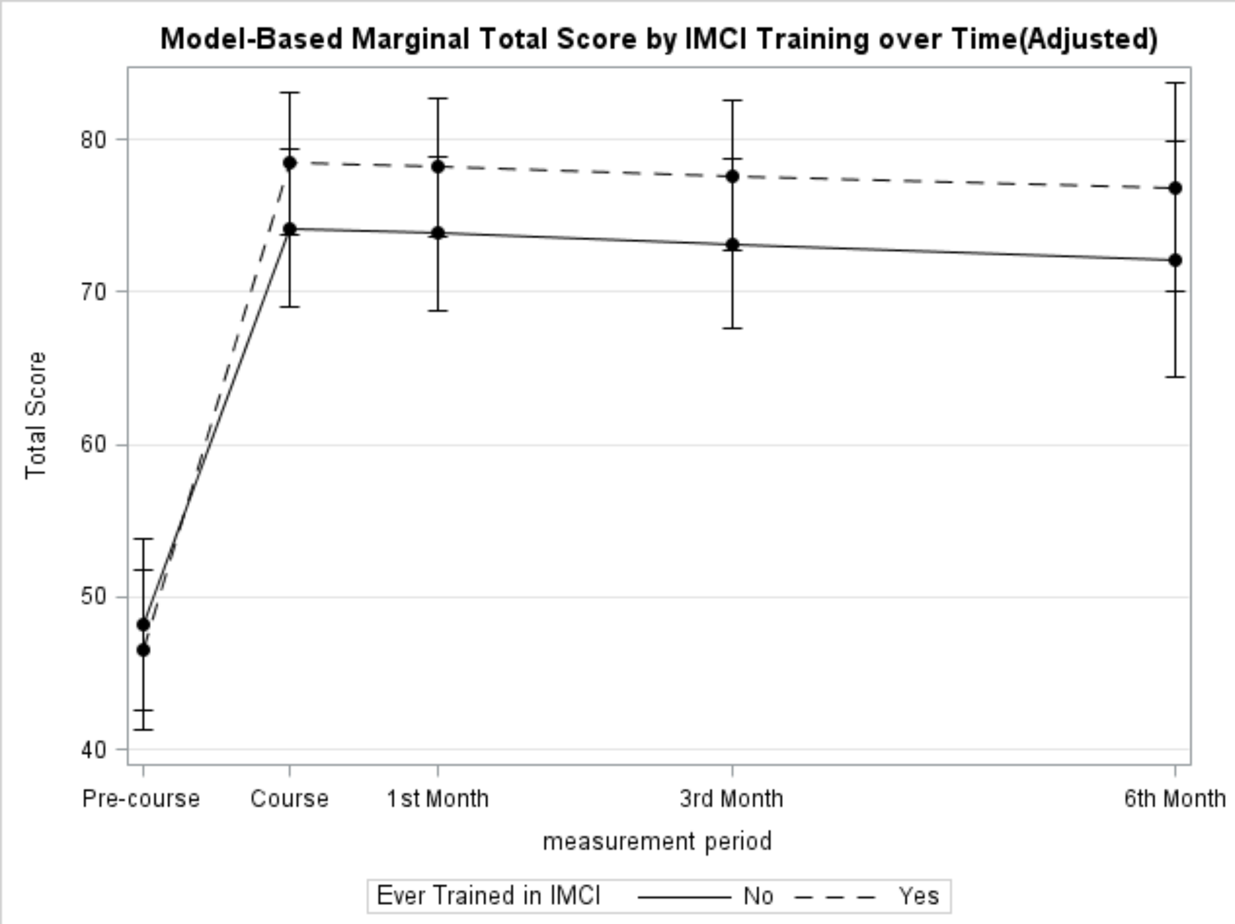
Figure 2:

- Caption: Model-Based Dehydration Sub-Score by IMCI Training over Time (adjusted)
- Legend: Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

Figure 3:

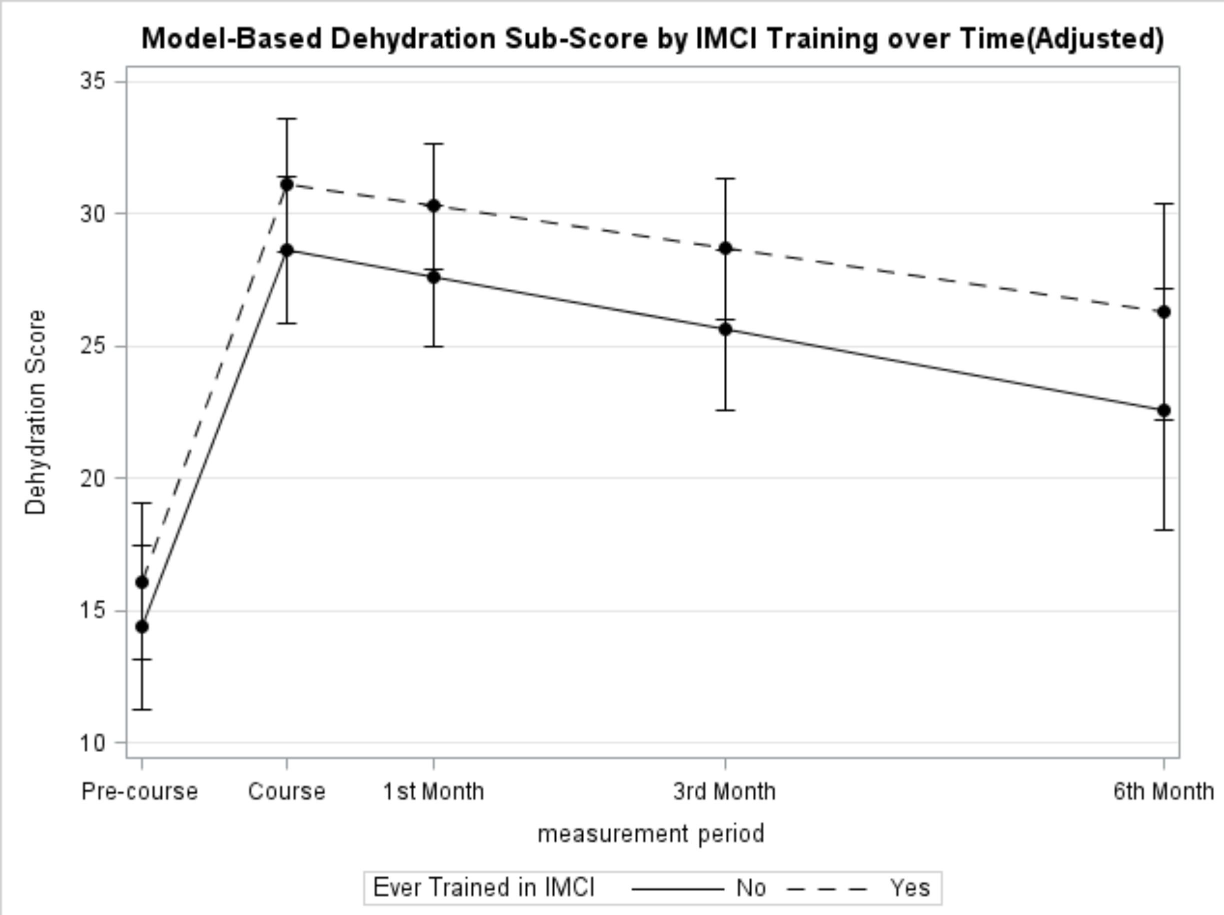
- Caption: Model-Based Pneumonia Sub-Score by IMCI Training over Time (adjusted)
- Legend: Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

Figure 1:



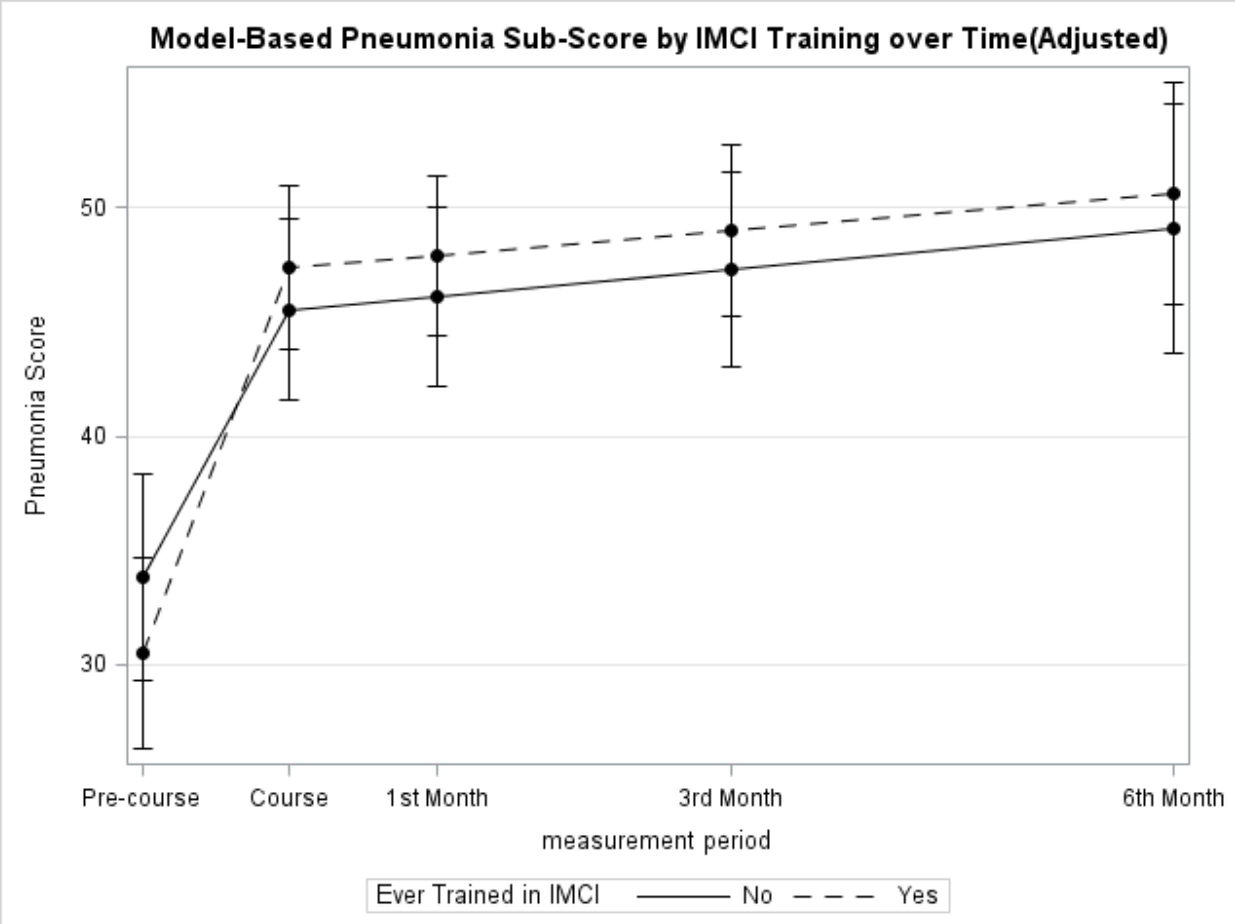
Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment.

Figure 2:



Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment.

Figure 3



Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, no previous training in neonatal resuscitation, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment.

Post-Hoc Testing/Sensitivity Analysis (Online Supplement):

Due to the significant loss of follow-up, we conducted a sensitivity analysis to examine if there was evidence of non-random missingness. Any student or course variable that was significantly different (0.1) between those completing 6-month follow-up and who did not or had significantly different course assessment scores was included in the linear mixed model.

Variables included in the sensitivity analysis included: year of initial training, degree of comfort with treatment of severe, ever previously trained in pediatric resuscitation, ever previously trained in neonatal resuscitation, ever previously trained in trauma resuscitation, ever previously trained in cardiopulmonary resuscitation, instructor mix, professional status, location of work, and perceived frequency of resuscitation > 1 month

Overall, a strong and significant effect was seen with knowledge acquisition (b= +28.7, ±1.8, p <0.0001) (online supplement table B), and there was a strong but significant loss of knowledge over time (b= -2.5 points/month, ±0.7, p 0.0022).

- IMCI was associated with a strong but not significant effect modification with knowledge acquisition (b= +4.0, ±3.9, p 0.3), and a weak but significant effect on knowledge retention (b= +2.8/month, ±0., p=0.002).

- Dehydration sub scores had strong and significant effect was seen with knowledge acquisition (b= +14.266, ±1.19, p <0.0001), and strong and significant loss of knowledge over time (b= -1.6/month, ±0.49, p 0.0022).
    - IMCI was associated with a neither a strong nor significant effect modification of dehydration knowledge acquisition (b= +2.3, ±2.5, p 0.36), nor knowledge retention (b= +0.9/month, ±0.6, p=0.15).

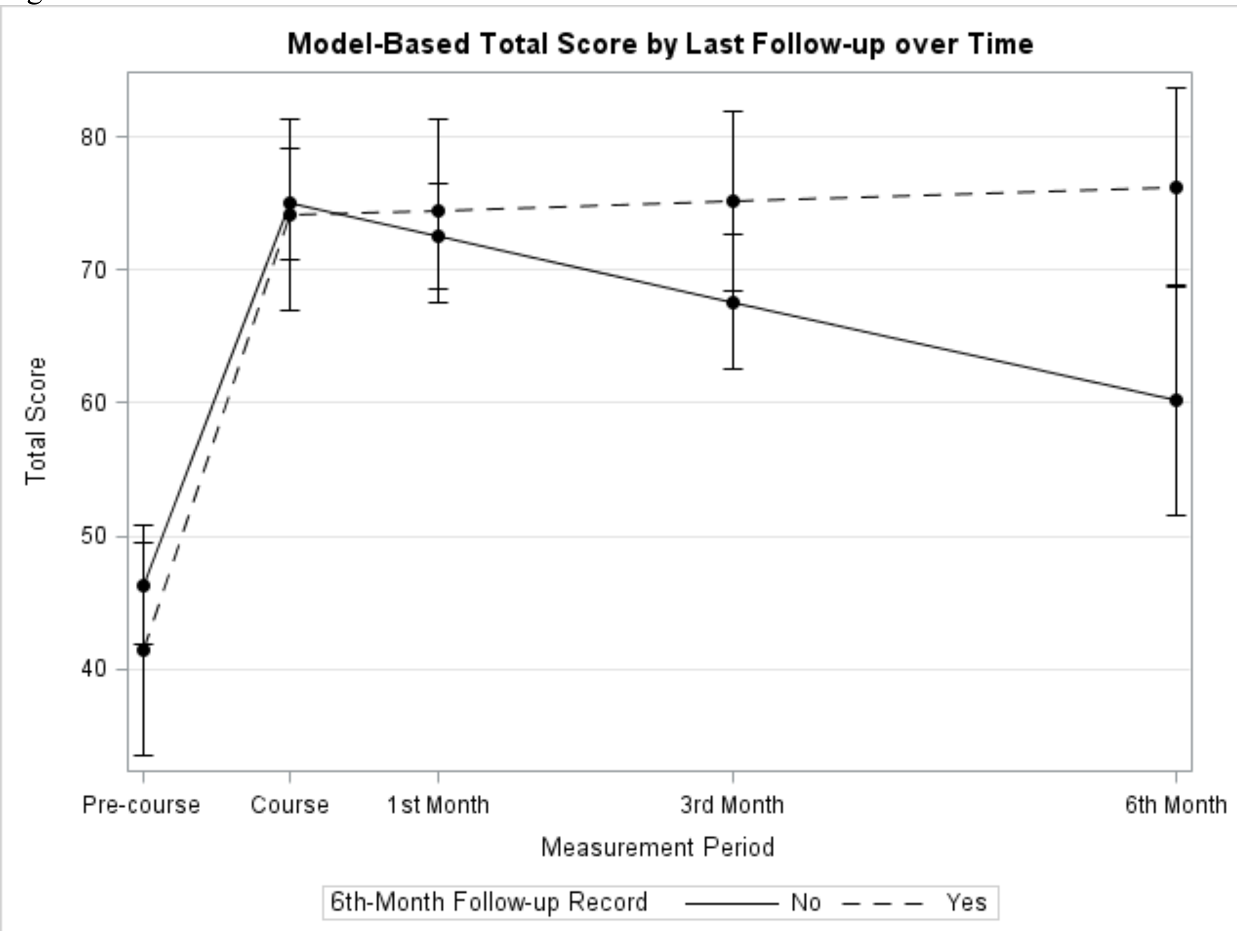
- Pneumonia sub scores had strong and significant effect was seen with knowledge acquisition (b= +14.4, ±1.35, p <0.0001, and weak and non-significant loss of knowledge over time (b= -1.0 /month, ±1.0/month, p 0.0566.
    - In the pneumonia sub score, previous IMCI training was associated with a weak and non-significant effect on knowledge acquisition (b= +1.6, ±2.9, p = 0.57) and a weak but significant gain on retention (b= +2.03, ±0.6, p 0.0006)

Table A: Provider Characteristics	Overall	Follow Up at 6 months	Lost to Follow up	p value
N	211	44	167	
Professional Status*		[n (%)]	[n (%)]	
Nurse	187 (90.8)	36 (19.3)	151 (80.7)	0.2038
Physician	19 (9.2)	6 (31.6)	13 (68.4)	
Location of work				
Clinic or Health post	127 (70.9)	27 (21.3)	100 (78.7)	0.7892
Hospital	52 (29.1)	12 (23.1)	40 (76.9)	
Other	32			
Mobile phone**				
Smart	111 (53.1)	25 (22.5)	86 (77.5)	0.5791
Text and Voice only	98 (46.9)	19 (19.4)	79 (80.6)	
No cell phone	3			
English spoken most commonly				
Yes	51 (24.2)	13 (25.5)	38 (74.5)	0.3492
No	160 (75.8)	31 (19.4)	129 (80.6)	
Perceived frequency of resuscitation > 1 month				
Yes	138 (66.7)	27 (19.6)	111 (80.4)	0.4004
No	69 (33.3)	17 (24.6)	52 (75.4)	
Missing	4			
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia				
Agree	147 (69.7)	33 (22.4)	114 (77.6)	0.3872
Disagree/Neutral	64 (30.3)	11 (17.2)	53 (82.8)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Dehydration.				
Agree	168 (79.6)	39 (23.2)	129 (76.8)	0.0952
Disagree/Neutral	43 (20.4)	5 (11.6)	38 (88.4)	
Resuscitation Success (perceived)				
0-25%	84 (40.8)	15 (17.8)	69 (82.1)	0.4269
26-50%	32 (15.5)	5 (15.6)	27 (84.4)	
51-75%	37 (18.0)	8 (21.6)	29 (78.4)	
76-100%	53 (25.7)	15 (28.3)	38 (71.7)	
Previous Resuscitation Training				
Pediatric	23 (11.1)	8 (34.8)	15 (65.2)	0.0877
Neonatal	21 (10.2)	4 (19.0)	17 (81.0)	1
Trauma	21 (10.2)	1 (4.8)	20 (95.2)	0.0846
CPR	73 (35.1)	21 (28.8)	52 (71.2)	0.0158
Year of the program***				
2014	162 (77.9)	39 (24.1)	123 (75.9)	0.023
2015 & 2016	46 (22.1)	4 (8.7)	42 (91.3)	

Instructor Type***				
IFO	52 (25.0)	33 (63.5)	19 (36.5)	<.0001
LT70LF	96 (46.2)	4 (4.2)	92 (95.8)	
GT70LF	39 (18.7)	5 (12.8)	34 (87.2)	
LFO	21 (10.10)	1 (4.7)	20 (95.2)	

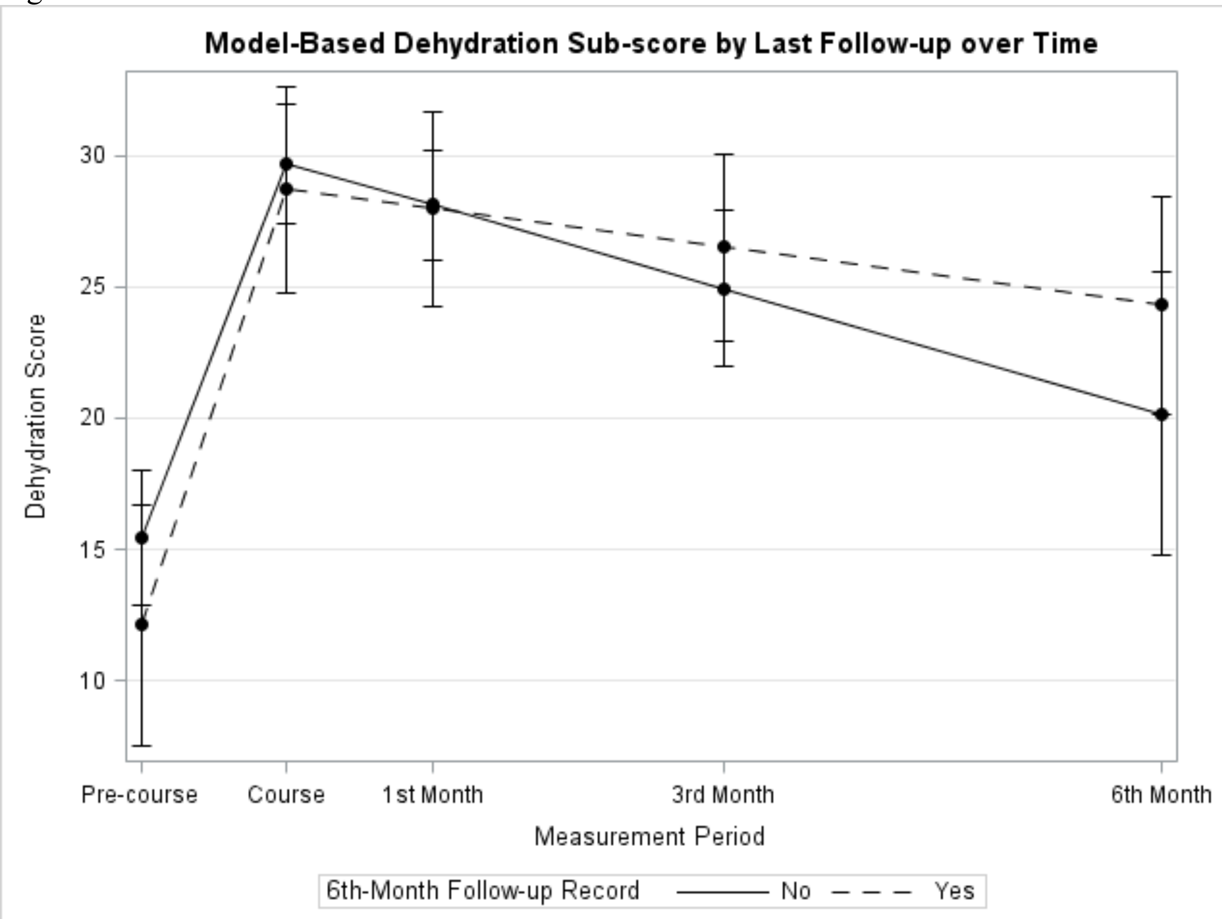
*5 participants did not report profession
** 2 did not report cellphone access
***3 did not report year of training or instructor type
Previous Pediatric Resuscitation = Pediatric Advanced Life Support, Emergency Triage Assessment and Treatment
Previous Neonatal Resuscitation = Neonatal Resuscitation Training, Helping Babies Breathe.
Previous CPR: Cardiopulmonary Resuscitation
Other includes hospital based (administrative/'other'= 29, not reported/missing = 3)

Figure A



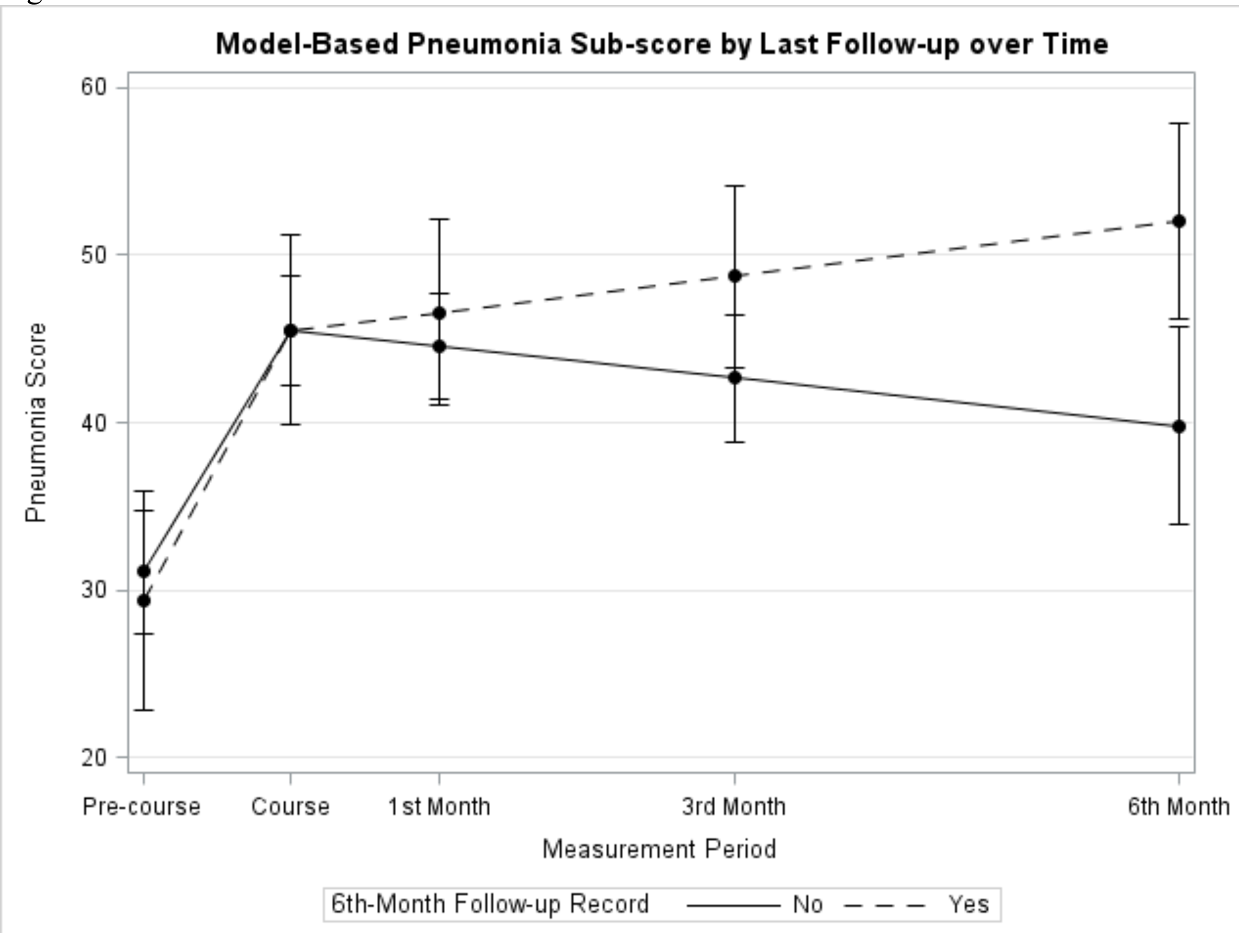
Plots were painted based on received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, has not been trained in neonatal resuscitation, and perception of frequency of resuscitation >1 month.

Figure B



Plots were painted based on received training in 2014, SE severe dehydration, no previous PALS training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, has not been trained in NRP/HBB, and perception of frequency of resuscitation >1 month.

Figure C



Plots were painted based on received training in 2014, SE severe dehydration, no previous PALS training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, has not been trained in NRP/HBB, and perception of frequency of resuscitation >1 month.

Table B: Predictor	estimate	standard error	p value
Total score			
Lost to follow up	-4.8359	3.7879	0.2031
Knowledge:			
Acquisition (pre-post)	28.6867	1.8359	<.0001
Retention (per month after course)	-2.4695	0.7669	0.0015
Interaction effect of Lost to follow up on:			
Acquisition (pre-post)	4.0047	3.9234	0.3085
Retention (per month after course)	2.8127	0.9098	0.0022
Dehydration			
Lost to follow up	-3.3199	2.2546	0.1423
Knowledge:			
Acquisition (pre-post)	14.2674	1.1907	<.0001
Retention (per month after course)	-1.5876	0.4962	0.0016
Interaction effect of Lost to follow up on:			
Acquisition (pre-post)	2.3257	2.5424	0.3613
Retention (per month after course)	0.8512	0.5912	0.1513
Pneumonia			
Lost to follow up	-1.6681	3.0972	0.5907
Knowledge:			
Acquisition (pre-post)	14.4176	1.3518	<.0001
Retention (per month after course)	-0.9508	0.4967	0.0569
Interaction effect of Lost to follow up on:			
Acquisition (pre-post)	1.6673	2.913	0.5677
Retention (per month after course)	2.034	0.5868	0.0006

Adjusting for: year of initial training, degree of comfort with treatment of severe, ever previously trained in pediatric resuscitation, ever previously trained in neonatal resuscitation, ever previously trained in trauma resuscitation, ever previously trained in cardiopulmonary resuscitation, instructor mix, professional status, location of work, and perceived frequency of resuscitation > 1 month.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	3
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	3
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	#3	State specific objectives, including any prespecified hypotheses	6
Study design	#4	Present key elements of study design early in the paper	7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	6
	#6b	For matched studies, give matching criteria and number of exposed and	6

		unexposed	
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	7
Bias	#9	Describe any efforts to address potential sources of bias	6,9
Study size	#10	Explain how the study size was arrived at	6
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	6-9
	#12b	Describe any methods used to examine subgroups and interactions	6-9
	#12c	Explain how missing data were addressed	8
	#12d	If applicable, explain how loss to follow-up was addressed	9
	#12e	Describe any sensitivity analyses	9
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	10
	#13b	Give reasons for non-participation at each stage	9
	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	10
	#14b	Indicate number of participants with missing data for each variable of interest	12
	#14c	Summarise follow-up time (eg, average and total amount)	12

Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	10-12
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
	#16b	Report category boundaries when continuous variables were categorized	10-12
	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	10-12
Key results	#18	Summarise key results with reference to study objectives	13
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	16
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	16
Generalisability	#21	Discuss the generalisability (external validity) of the study results	16
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

 This checklist was completed on 05. February 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

Knowledge acquisition and retention following Saving Children's Lives course for healthcare providers in Botswana: a longitudinal cohort study

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Secondary Subject Heading:	Emergency medicine, Global health, Health services research, Paediatrics
Keywords:	MEDICAL EDUCATION & TRAINING, ACCIDENT & EMERGENCY MEDICINE, Paediatric intensive & critical care < PAEDIATRICS, PRIMARY CARE, Community child health < PAEDIATRICS, Resuscitation

SCHOLARONE™
Manuscripts

Title: Knowledge acquisition and retention following Saving Children's Lives course for healthcare providers in Botswana: a longitudinal cohort study

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Short Title: 'Saving Children's Lives' Increases Provider Knowledge

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Abbreviations: serious childhood illness (SCI), Saving Children's Lives (SCL), abbreviated high intensity training (aHIT), Integrated Management of Childhood Illness (IMCI), World Health Organization (WHO), low and middle-income countries (LMICs), international faculty (IF), local faculty (LF), international faculty only (IFO), < 70% local faculty (LT70LF), > 70% local faculty (GT70LF), local faculty only (LFO)

Table of Contents Summary:
Saving Children's Lives training significantly increases healthcare provider knowledge to care for seriously ill children and is highly relevant to middle-income country health systems.

Contributors' Statement:

Dr Meaney conceptualized and designed the study, carried out the initial analyses, designed the data collection instruments, drafted the initial manuscript, and critically reviewed the manuscript for important intellectual content.

Mr Setlhare designed the data collection instruments, collected data, carried out the initial analyses, and critically reviewed the manuscript for important intellectual content.

Dr Joyce collected data, carried out the initial analyses, and critically reviewed the manuscript for important intellectual content.

Mrs Kgosiesiele, Dr Kalenga and Jibril conceptualized and designed the study, coordinated and supervised data collection.

Dr Kloeck coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content.

Drs Mensinger, Zhang, and Smith made substantial contributions to analysis and interpretation of data, and critically reviewed the manuscript for important intellectual content.

Dr Mazhani, deCaen and Steenhoff conceptualized and designed the study, and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Data Sharing Statement: copy of the dataset is available by emailing the corresponding author (meaneypa@stanford.edu)

Abstract

Objectives

Millions of children die every year from serious childhood illnesses. Most deaths are avertable with access to quality care. Saving Children's Lives (SCL) includes an abbreviated high intensity training (SCL-aHIT) for providers who treat serious childhood illnesses. The objective of this study was to examine the impact of SCL-aHIT on knowledge acquisition and retention of providers.

Setting:

76 participating centers who provide primary and secondary care in Kweneng District, Botswana.

Participants:

Doctors and nurses expected by the District Health Management Team to provide initial care to seriously ill children, completed SCL-aHIT between January 2014 and December 2016, submitted demographic data, course characteristics, and at least one knowledge assessment.

Methods:

Retrospective, cohort study. Planned and actual primary outcome was adjusted acquisition (change in total knowledge score immediately after training) and retention (change in score at 1, 3 and 6 months), secondary outcomes were pneumonia and dehydration subscores. Descriptive statistics and linear mixed models with random intercept and slope were conducted. Relevant IRBs approved this study.

Results:

211 providers had data for analysis. Cohort was 91% nurses, 61% clinic/health-post based, and 45% pre-trained in Integrated Management of Childhood Illness (IMCI). A strong effect of SCL-aHIT was seen with knowledge acquisition (+24.56±1.94, $p < 0.0001$), and loss of retention was observed (-1.60±0.67/month, p=0.018). IMCI training demonstrated no significant effect on acquisition (+3.58±2.84, p=0.211 or retention (+0.20±0.91/month, p=0.824) of knowledge. On average, nurses scored lower than physicians (-19.39±3.30, $p < .0001$). Lost to follow-up had a significant impact on knowledge retention (-3.03 ± 0.88/month, p=0.0007).

Conclusions:

Abbreviated high intensity training for care of the seriously ill child significantly increased provider knowledge and loss of knowledge occurred over time. IMCI training did not significantly impact overall knowledge acquisition nor retention, while professional status impacted overall score and loss to follow-up impacted retention.

Strengths and limitations of this study

- Doctors and nurses working in community clinics and district hospitals in a middle-income country gained significant knowledge immediately after the 2-day Saving Children's Lives course.
- On serial reassessments up to 6 months later, knowledge gained deteriorated significantly, those who did not complete follow up at 6 months had faster deterioration of knowledge compared to those who did.
- There was significant loss to follow-up during the study period, and those doctors and nurses had significantly increased loss of knowledge over time.
- Outcomes are limited to provider knowledge, not actual or reported performance.

Introduction

Each year, severe pneumonia, shock from diarrheal dehydration and sepsis are responsible for 25% of 5.1 million child deaths that occur worldwide.[1,2] Over 1 million children die each year due to lack of effective, low-cost interventions being available and utilized appropriately.[3] Access to quality healthcare is a global challenge, and timely and effective treatment for pneumonia and diarrhea are essential components.[4-6]

A child mortality audit in Botswana between 2011-2013 demonstrated that 46% of pediatric in-hospital deaths were due to severe pneumonia, diarrheal dehydration and sepsis.[7] 33% of in-hospital pediatric deaths occurred within the first 24 hours, an indication that children arrived critically ill. 26% of all in-hospital deaths were considered avoidable, with an average of 2.6 modifiable factors contributing to each death.[7] Delayed or inadequate recognition and treatment of serious illness were major modifiable factors, and over 50% of factors were attributed to provider performance.

Healthcare providers in Botswana are trained to care for ill children using the Integrated Management of Childhood Illness (IMCI). IMCI is a training program endorsed by the World Health Organization (WHO) to train healthcare providers to care for children in low and middle-income countries (LMICs). However, studies have demonstrated that after health providers receive IMCI training, one-third to one half of seriously ill children are not identified and do not receive correct treatment for potentially life-threatening conditions.[8-10]

Saving Children's Lives (SCL) program is a collaboration between the Botswana Ministry of Health, the University of Botswana, Botswana University of Pennsylvania Partnership, Children's Hospital of Philadelphia Center for Global Pediatric Critical Care, and the American Heart Association to improve the quality of care for seriously ill or injured children. Saving Children's Lives abbreviated high-intensity training (SCL-aHIT) is a 2-day training focused on the knowledge and skills a healthcare provider needs to optimally recognize and initiate stabilizing treatment in the community clinic, primary or district hospital setting.

We hypothesized that SCL-aHIT would lead to significant knowledge acquisition and retention by healthcare providers. We also hypothesized that IMCI training would not have significant impact on knowledge acquisition or retention. Further, we hypothesized that provider, training or work environment characteristics may impact knowledge acquisition and retention. Finally, we hypothesized that SCL-aHIT may impact knowledge of pneumonia and diarrhea scores may have differential acquisition and retention.

Methods:

Study design:

This retrospective cohort study was conducted to examine the impact of district-level SCL-aHIT on provider knowledge in Kweneng District, Botswana. All components of the SCL program were active during the study period. Data was extracted from the SCL administrative database and included participant demographics and knowledge assessments. Our primary outcome was total score acquisition with secondary outcomes of total score retention, and pneumonia and diarrhea subscores of both acquisition and retention.

Setting:

Kweneng District, Botswana, has a population of 304,000, with 83% people living within 8 km of a health facility (100% within 15km).[11-13] There is one district hospital, two primary hospitals, nine clinics with beds, and sixty-four health posts and clinics without beds in the district. The estimated doctor/population ratio is 1:550 and nurse/population ratio of 1:80.

Cohort Description:

Cohort consisted of a convenience sample of physicians and nurses from community clinics, health posts, primary and district hospitals. Providers were identified for training by the Kweneng District Health Management team based on if they were expected to provide initial stabilizing care to seriously ill children in their position. All subjects who participated in SCL-aHIT, completed demographic data and at least one knowledge assessment were eligible for inclusion. To minimize selection bias, follow-up assessments were attempted all providers identified in Kweneng district completed training.The SCL implementation team attempted to follow-up with participants of the training sessions in person or by phone. There were two attempts to complete the assessment at each time point for all course participants. More attempts were not possible due to program limitations.

Saving Children's Lives

The SCL program employs 5 major implementation strategies:

Implementation Strategy 1: Abbreviated High-Intensity In-Service Training:

SCL-aHIT is a contextualized version of the American Heart Association's Pediatric Emergency Assessment Recognition and Stabilization program. The contextualization process and initial training program has been described previously.[14] It is a combination of didactics, skills stations and simulated patient scenarios. To increase peer to peer learning and instructor situational awareness, didactics and final exam employed audience response software. While Rowe et al defined high intensity training as having a duration > 5 days which included interactive sessions (e.g. role play),[15] we defined abbreviated high intensity training (aHIT) as having interactive sessions but with a training duration < 5 days.

Implementation Strategy 2: Serial Facility Readiness Assessments:

The implementation team conducted bi-monthly Facility Readiness Assessments (FRA). The FRA is a focused inventory of personnel, equipment, and supplies relevant to treatment of seriously ill or injured children who present to clinics, health posts, or wards (hospitals). Estimated time to completion was one hour, and findings were immediately reported to the on-duty leadership, active issues reviewed, and solutions identified.

Implementation Strategy 3: Longitudinal Provider Knowledge Assessment

The knowledge assessment is a 6-item multiple-choice questionnaire was administered pre SCL-aHIT training, immediately following, and at one-, three-, and six- months. The assessment targeted to basic content regarding recognition and treatment of severe dehydration and moderate-severe pneumonia. Question types include 'select all that apply' and single best answer. Correct volume and rate of fluid administration for severe dehydration were consistent with current WHO and PALS guidelines. Choice of antibiotics for pneumonia was dependent on reported location of work and aligned with national guidelines.

Implementation Strategy 4: Bi-directional Active Feedback between Front-Line Providers and Health System Leadership.

The implementation team actively reported to health system leadership biannually and received feedback on program implementation strategies (training, facility readiness, and provider knowledge). Reports were conducted in person with District Health Management Team (DHMT) leadership (District Hospital Superintendent, Matron, and Chief Medical Officer) as well as Ministry of Health (Deputy Permanent Secretary of Clinical Services, Public Health, Permanent Secretary to the Minister of Health). These results, as well as the feedback from health system leadership, were reported back to the instructor group biannually at instructor "Bootcamps".

Implementation Strategy 5: Development and maintenance of a clinically relevant instructor core.

Instructor candidates were identified by instructors based on course performance, interest in subject matter, and interpersonal skills. After receiving approval from the DHMT, instructor candidates underwent a two-day instructor training focused on adult learning strategy, simulated patient scenario facilitation, and roles and responsibilities of being an active instructor. Then, they were monitored with structured feedback by senior SCL faculty for a minimum of two courses.

Outcomes

Data extracted from the SCL administrative database for analysis include self-reported provider demographics and serial knowledge assessment responses. Total and subscores were treated as continuous variables (potential range from 0-100). Provider demographics included: professional status, work location, type of personal mobile phone (smart vs other), language most commonly spoken, IMCI subtypes (time since training, training duration - short vs long), other previous resuscitation training, perception of resuscitation, and course multiple choice question (MCQ) score. A smart phone was defined as a mobile phone that had applications, access to internet and email. As SCL-aHIT employed audience response software as an education tool, the SCL program tracked smartphone ownership as a surrogate for comfort with technology to monitor possible impact on knowledge acquisition. The SCL program was initiated using highly experienced pediatric resuscitation education experts and transitioned to newly trained local instructors during the study period. To control for confounding due top variation in instructor experience, training characteristics included year of training and instructor mix. We defined the instructor mix of the initial training to be of four types: international faculty only (IFO), < 70% local faculty (LT70LF), > 70% local faculty (GT70LF), and local faculty only (LFO). We also defined training by the year initial SCL training was conducted: Jan 1-Dec 31 for 2014 (IF led, full program support), 2015 (LF led, high degree of IF supervision, full program support), and 2016 (LF led, minimal IF supervision, minimal program support).

Statistical Approach:

The statistical analysis was performed using SAS software, version 9.4. We conducted exploratory analyses to test for potential confounding between IMCI training and knowledge acquisition and retention. Means and standard deviations were presented for continuous variables, while frequency and percent were presented for discrete variables. Difference in participant or course characteristics between IMCI and non-IMCI groups were tested with Chi-square test for discrete variables. Difference in immediate post-training assessment score among participant or course characteristics were tested with independent-samples t-tests (Professional Status, English spoken most commonly, Perceived frequency of resuscitation > 1 month, I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia/ Severe Dehydration, Year of the program, Previous Resuscitation Training, Smart phone usage,) or one-way ANOVA (Location of work, Resuscitation Success (perceived), Instructor Type), as appropriate.

To answer the study's primary hypothesis, that participation in the SCL training would lead to significant increases in knowledge from baseline to post-course assessments and that the knowledge would be retained over the study period, we used a linear mixed model approach.

Best model fit was achieved with two linear segments, with baseline to immediate post-training as the first segment (knowledge acquisition), and immediate post-training to 6-month follow-up as the second segment (knowledge retention). Random intercepts were fit to allow for subject-specific baseline scores and random slopes were fit to the initial piece-wise segment to allow for subject-specific knowledge acquisition scores, as well as the second piece-wise segment to allow for subject-specific knowledge retention. The first model fit was the unconditional means model which includes only the random intercept. Model 2 was the unconditional growth model which included the fixed effects for each time segment, the random intercept, and the random slope for time segment 1 and 2. We show the proportion of variance in knowledge change over time that is explained by the complete Knowledge Assessment at one-, three-, and six- months after SCL-aHIT training (and subsequently by IMCI training and then the covariates) by examining the decrease in the within person residual variance from one model to the next. To answer hypothesis 2, Model 3 adds IMCI training to the unconditional growth equation. The main effect of IMCI assessed the difference in baseline knowledge level between the IMCI versus non-IMCI group. An interaction effect between previous IMCI training and the piece-wise time effects was also added into the model to assess whether IMCI training enhanced or diminished knowledge acquisition and/or retention. Model 4 presents the confounder adjusted model. Several covariates were included in this model a priori (year of training, location of work). To maintain a relatively parsimonious model yet still use a conservative cut-off for issues of confounding, we retained any variable that was significantly different between IMCI and non-IMCI participants or had significantly different course assessment scores in bivariate analysis ($p \leq 0.10$). To evaluate for non-random loss of follow-up (non-response bias), we conducted a sensitivity analysis that involved creating a variable for those missing 6-month assessments and those with 6-month assessment. Since these analyses revealed patterned missingness (dropouts had lower knowledge retention), we added this variable as a fixed factor to further control for loss-to-follow-up. We performed model diagnostics including testing for multivariate normality of residuals and testing for linearity of the trend in each time segment. Multicollinearity was assessed with Pearson correlation coefficient ($r<0.8$) among the potential confounders.

Ethics/IRB Considerations,:

We used the STROBE cohort checklist when writing our report.[16] The study was approved with a waiver of informed consent by the ethics boards of the Botswana Ministry of Health and the University of Pennsylvania.

Patient and Public Involvement statement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Results:

Description of cohort

Between January 2014 and December 2016, 211 providers had data available for analysis. 91% (187) were nurses, and 61% (127) were clinic/health post based and 25% (52) hospital based (Table 1). 98% (206) of providers had a mobile phone and 53% (111) reported owning a smart phone. 24% reported English was the most commonly used language. 67% self-reported that they resuscitated a seriously ill child at least once a month, and 30% and 20% of participants were not comfortable with the initial steps of stabilizing a child with severe pneumonia or diarrhea, respectively. 41% (84) of providers perceived resuscitation to be successful in less than 25% of cases where they work. Only 45% (95) reported previous IMCI training. Of providers with previous IMCI training, 74% (70) reported that the duration of IMCI training was less than 7 days (Table 2). 38 (40%) received IMCI training > 5 years ago and 32 (34%) < 2 years ago. Pediatric, neonatal or trauma resuscitation training was less than 12%, while 35% (73) had received CPR training. 78% (162) of participants received training in 2014, while 29% (60) were taught by an instructor group with 70% local instructors or only local instructors.

Sensitivity Analysis

To determine whether there were biases due to loss to follow-up, we created two groups: one group that had 6-month follow-up score and one group that did not have 6-month follow-up. We compared the acquisition of knowledge trajectory and retention of knowledge trajectory to ensure they were similar. Analysis showed differences in knowledge retention between the groups: the group with 6-month follow-up did not have a significantly better knowledge acquisition (+1.26, se=3.69, p=0.7329), but demonstrated significantly better retention

(+3.03/month, se=0.88, p=0.0007). To control for this bias, we entered this variable into the confounder-adjusted piecewise regression models described below (Model 4, Tables 3, 4, and 5). See Supplementary Table and Figures for results of the sensitivity analysis.

Description of Model

The assumption of multivariate normality was adequately met. Linearity was satisfied within each time segment. No multi-collinearity issue was found. Covariates included in the final model included: year of initial training, professional status, smart phone usage, language spoken most commonly, degree of comfort with treatment of severe pneumonia, location of work, perceived frequency of resuscitation, and presence/absence of 6-month follow-up.

A strong and significant main effect was seen for knowledge acquisition due to SCL-aHIT (time: pre to post) (b= +24.56 ±1.94, p<.0001), and loss of knowledge over time (b= -1.60 ±0.67/month, p=0.018). The proportion of variance in total scores knowledge change over time explained by the SCL education was 56.17% (R^2, Table 3). For dehydration subscores, a strong and significant main effect was seen for both knowledge acquisition (b=+14.58 ±1.29, p <0.001), and loss of knowledge over time (b= -1.10 ±0.39/month, p=0.0055). The proportion of variance in dehydration subscores knowledge change over time explained by the SCL education was 51.90% (R^2, Table 4). For pneumonia subscores, a strong and significant main effect was also seen for knowledge acquisition (b= +9.83 ±1.48, p <0.001), and no significant change in knowledge over time (b= -0.34 ±0.42/month, p=0.4229). The proportion of variance in pneumonia subscores knowledge change over time explained by the SCL education was 47.73% (Table 5)

To test the second hypothesis, IMCI training had no effect on knowledge at baseline (b=-0.52 ±2.45, p=0.834), knowledge acquisition (b=+3.58 ±2.84, p=0.211), knowledge retention (b=+0.20 ±0.91/month, p=0.824), for total scores. IMCI training explained 0.07% of additional variance in total score change. As for dehydration subscores, IMCI training had no effect on knowledge at baseline (b=+1.06±1.57, p=0.5026) knowledge acquisition (b= +0.12 ±1.90, p=0.9513), or knowledge retention (b= +0.39 ±0.54/month, p=0.4681). IMCI training explained 0.17% of additional variance in dehydration score change. For pneumonia subscores, IMCI training had no effect on knowledge at baseline (b=-1.74±1.94, p=0.3711)There was no difference in knowledge acquisition (b=3.65±2.17, p=0.096) or knowledge retention (b= -0.39 ±0.55/month, p=0.4829). IMCI training explained 0.11% of additional variance in pneumonia score.

Our final hypothesis was examined in the confounder-adjusted models (see Model 4 in Tables 3, 4, and 5). On average, nurses scored significantly lower than physicians at all time points: (b= -19.39 ±3.30, p <.0001) on total score, (b = -7.21±1.89, p=0.0002) on dehydration sub-score, and (b= -10.20±2.30, p<.0001) on pneumonia sub-score. Compared to those who worked in hospitals, participants who worked in clinics/health posts scored significantly worse on dehydration: (b= -2.24±1.12, p=0.0481). Perceived frequency of resuscitation, language, perceived comfort with treatment of pneumonia, smart phone usage, year of training and completeness of follow-up had no significant effect on total scores or the dehydration or pneumonia subscores.

Model-based mean scores for each assessment were calculated based on populations that represented the majority of the cohort: those who had SCL initial training in 2014, were nurses, used smartphones, spoke non-English most commonly, were comfortable treating of severe pneumonia, worked in clinic/health post, reported frequency of resuscitation >1/month, and did not complete a 6-month assessment were plotted (Figure 1-3).

Discussion:

This study demonstrates for the first time that SCL-aHIT significantly increases provider knowledge acquisition in the recognition and treatment of serious childhood illness. This is the largest study to our knowledge to report knowledge retention outcomes of providers who care for seriously ill children outside of academic centers in a low or middle income country. While previous IMCI training did not decrease knowledge acquisition, professional status and completing follow up assessments impacted scores significantly. There was significant loss to follow-up during the study period, and while the adjusted model demonstrated worse knowledge retention than those who completed 6-month follow-up, we are limited in our ability to draw strong conclusions regarding knowledge the true rate of loss of retention.

This increase in knowledge may be due to the characteristics of training, and our study is consistent with previous studies that demonstrate high intensity training being the most effective single implementation strategy to improve healthcare worker performance.[15,17] Rowe et al found that high intensity training had the greatest median training effect (11, IQR 8-15) compared to low-intensity training only (8, IQR 2-22), supervision (8, IQR 3-17), group problem solving (8, IQR 6-21), regulation/governance (5, IQR -1-20) or job aids (-3, IQR -7-+7). This is a similar increase Tusiyenge et al found when examining pediatric resuscitation knowledge acquisition and retention of final year medical students after a high-intensity training in an academic referral hospital setting in Malawi.[18] Further, the high impact of an abbreviated (2-day) high-intensity training is notable as shortened (5-10 day) IMCI training has been associated with a 2 to 16-point loss of treatment effect over standard (11-day) training.[9] While SCL-aHIT demonstrated a larger effect than the range in the systematic review, our outcomes were limited to knowledge assessment and the difference in magnitude needs to be interpreted with caution.

There was significant loss of knowledge after SCL's abbreviated high intensity training. At the estimated rate found in this study, knowledge would return to baseline in under 2 years for those who completed 6 month follow-up, while those who did not complete follow-up would return to baseline in less than 8 months. While Tuyisenge and colleagues demonstrated retention up to 9 months after training final year medical students in pediatric resuscitation,[18] our study is consistent with other studies in resuscitation training that demonstrate rapid loss of knowledge or skills, often in as little as in 6-12 weeks after training.[19-23] This has also been seen with clinical management of malaria[24] as well as with IMCI[10]. While the loss to follow-up in this study only allows us to estimate a range of the rate of knowledge loss, is notable that the most rapid estimate is not as rapid as other studies. Several reasons may account for this. It may be due to the contextualization process to ensure training was relevant to disease epidemiology and health system resources in Botswana. It may have been due to other components of SCL program besides aHIT. The SCL program integrates support in inventory of relevant medication and functioning equipment as part of its training and it provides immediate individual education on follow-up assessments by a master trainer. It is possible that similar results could have been obtained just from inventory support. The SCL program utilizes active reporting of training results to local health leadership – this may have stimulated additional feedback and support through administrative communication independent of the SCL program. Finally, it may be due to regression to the mean, as baseline knowledge scores were low and thus could only improve.

In this study, previous IMCI training did not significantly impact provider knowledge gained or retained from SCL-aHIT. That overall knowledge gained from SCL-aHIT was not negatively impacted supports the theory that programs such as SCL that focus on serious childhood illness may be an added value and not redundant to IMCI training. This may be especially important in environments where quality of pneumonia and diarrhea care is poor despite IMCI implementation. While IMCI-trained workers are more likely to correctly classify illnesses, administer oral therapies, employ rational antibiotic use, vaccinate children, and counsel families on adequate nutrition for moderate illness,[8,25] IMCI has limited impact on care delivery of the seriously ill child.[8-10] If there was significant overlap in content between SCL and IMCI, we might expect higher baseline scores and decreased acquisition. Alternatively, it may be that current existing IMCI training is not optimally effective.

Nurses, on average, scored significantly lower than physicians. This may be due to differences in pre-clinical education, in-service training, or unmeasured provider and environment characteristics that are highly correlated with professional status. Nevertheless, as nurses are the major training target for SCL-aHIT, further modifications to course content, structure or follow-up training may be needed.

Access to quality treatment of pneumonia and diarrhea are major contributors to avertable mortality worldwide.[4-6] Studies of provider performance show that standard guidelines were only followed 30-40% of the time, and often led to misallocation of resources.[26] Further, studies have shown that children with complex serious illness often receive worse care than those with milder, straightforward presentations.[27,28] This poor quality of services for treatable conditions is directly responsible for over 5 million deaths each year and contributes to decreased utilization of services, which accounts for another 3.6 million deaths.[6] A sustained and integrated improvement of provider knowledge and resource awareness is needed to address these gaps that currently limit systems to provide quality care.

Limitations:

As with any study there were several limitations. Use of an administrative database and infrastructure for the SCL program may have contributed to non-random loss to follow-up. Although effect was minimized through the conducted sensitivity analyses (see appendix), the study should be repeated with stronger support for follow-up data collection as well as training. Our outcome data was limited to knowledge assessments, and future studies that examine operational performance or patient outcomes are needed. The knowledge assessments have not been previously validated, and future studies should have multiple versions to better discriminate retention of test knowledge versus content knowledge. Finally, use of two time piece model assumes linearity throughout the follow-up period, and the true slope of knowledge retention may be non-linear.

Conclusion:

Abbreviated high intensity training focused on the seriously ill child significantly increases provider knowledge for both clinic and hospital-based providers. There appears to be significant loss of knowledge after initial training. IMCI training did not significantly impact overall knowledge acquisition or retention, but professional status impacted overall scores and loss to follow-up impacted retention of knowledge. In health systems where access to quality care for the seriously ill child is poor, programs such as Saving Children's Lives may have a significant impact if knowledge retention can be addressed.

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Table 1: Provider Characteristics

	Overall	IMCI trained	No IMCI	p value
N	211	95	116	
Professional Status*		[n (%)]	[n (%)]	
Nurse	187 (90.8)	91 (48.7)	96 (51.3)	0.0061
Physician	19 (9.2)	3 (15.8)	16 (84.2)	
Location of work***				
Clinic or Health post	127 (61.10)	62 (48.8)	65 (51.2)	0.2186
Hospital	52 (25.0)	23 (44.2)	29 (55.8)	
Other	29 (13.9)	9 (31.0)	20 (69.0)	
Mobile phone**				
Smart	111 (53.1)	57 (51.4)	54 (48.6)	0.0684
Text and Voice only or no cell phone	98 (46.9)	38 (38.8)	60 (61.2)	
English spoken most commonly				
Yes	51 (24.2)	15 (29.4)	36 (70.6)	0.0101
No	160 (75.8)	80 (50.0)	80 (50.0)	
Perceived frequency of resuscitation > 1 month****				
Yes	138 (66.7)	65 (47.1)	73 (52.9)	0.4896
No	69 (33.3)	29 (42.0)	40 (58.0)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia				
Agree	147 (69.7)	78 (53.1)	69 (46.9)	0.0004
Disagree/Neutral	64 (30.3)	17 (26.6)	47 (73.4)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Dehydration.				
Agree	168 (79.6)	80 (47.6)	88 (52.4)	0.1342
Disagree/Neutral	43 (20.4)	15 (34.9)	28 (65.1)	
Resuscitation Success (perceived)*				
0-25%	84 (40.8)	42 (50.0)	42 (50)	0.2832
26-50%	32 (15.5)	13 (40.6)	19 (59.4)	
51-75%	37 (18.0)	12 (32.4)	25 (67.6)	
76-100%	53 (25.7)	26 (49.1)	27 (50.9)	
Previous Resuscitation Training				
Pediatric****	23 (11.1)	12 (52.2)	11 (47.8)	0.4
Neonatal*	21 (10.2)	8 (38.1)	13 (61.9)	0.5538
Trauma*	21 (10.2)	7 (33.3)	14 (66.7)	0.2911
CPR***	73 (35.1)	29 (39.7)	44 (60.3)	0.3361
Year of the program***				
2014	162 (77.9)	77 (47.5)	85 (52.5)	0.3128
2015 or 2016	46 (22.1)	18 (39.1)	28 (60.9)	

Instructor Type***				
IFO	52 (25.0)	28 (53.9)	24 (46.1)	0.3872
LT70LF	96 (46.2)	44 (45.8)	52 (54.2)	
GT70LF	39 (18.8)	16 (41.0)	23 (59.0)	
LFO	21 (10.0)	7 (33.3)	14 (66.7)	

*5 participants did not report profession, resuscitation success (perceived), previous neonatal resuscitation or trauma training
** 2 did not report cellphone access
***3 did not report location of work, previous CPR training, year of training or instructor type
****4 did not report previous pediatric resuscitation training or perceived frequency of resuscitation
Previous Pediatric Resuscitation = Pediatric Advanced Life Support, Emergency Triage Assessment and Treatment
Previous Neonatal Resuscitation = Neonatal Resuscitation Training, Helping Babies Breathe.
Previous CPR: Cardiopulmonary Resuscitation
Other includes hospital based (administrative/'other')

Table 2: Characteristics of provider previous IMCI training

	N=95
Time since training	% (N)
< 6 months	14% (13)
>6months-2years	20% (19)
2-5yr	26% (25
>5 years	40% (38)
IMCI Course Duration	% (N)
< 7 days	74% (70)
≥ 7 days	26% (25)

Table 3: Models for Total Score Acquisition and Retention in Relation to Previous IMCI Training

	Model 1 (N = 679)		**Model 2 (N = 679)**		**Model 3 (N = 679)**		**Model 4 (N =655)**	
	γ (SE)	***p***	**γ (SE)**	***p***	**γ (SE)**	***p***	**γ (SE)**	***p***
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**IMCI training added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	60.20 (0.90)	<.0001	43.08 (1.32)	<.0001	44.16 (1.78)	<.0001	45.70 (3.82)	<.0001
Previous IMCI training (yes vs. no)					-2.41 (2.65)	0.3641	-0.52 (2.45)	0.8336
Location of work (Clinic or Health post vs. Hospital)							-2.72 (1.96)	0.1677
Location of work (Other vs. Hospital)							-7.04 (2.77)	0.0125
Profession status (Physician vs. Nurse)							19.39 (3.30)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.91 (1.74)	0.6022
English spoken most commonly (Yes vs. No)							1.93 (2.28)	0.3989
Comfortable with treatment of severe pneumonia (Agree vs. Disagree/Neutral)							0.02 (1.77)	0.9903
Smartphone usage (Yes vs. No)							0.72 (1.57)	0.6453
Year of program (2014 vs. 2015 or 2016)							-4.04 (2.33)	0.0852
Had 6-month assessment (Yes vs. No)							1.91 (1.89)	0.313
Rate of Change (slope for timepiece one)								
Knowledge acquisition			26.37 (1.32)	<.0001	24.61 (1.88)	<.0001	24.56 (1.94)	<.0001
previous IMCI training (yes vs. no)					3.89 (2.79)	0.1655	3.58 (2.84)	0.2113
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-1.49 (0.46)	0.0014	-1.59 (0.66)	0.0172	-1.60 (0.67)	0.018
previous IMCI training (yes vs. no)					0.17 (0.92)	0.8574	0.20 (0.91)	0.824
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	399.07 (25.19)	<.0001	174.92 (18.14)	<.0001	174.79 (18.15)	<.0001	172.68 (17.89)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	41.59 (16.39)	0.0056	180.80 (39.60)	<.0001	181.40 (39.72)	<.0001	99.19 (34.29)	0.0019
Slope for knowledge acquisition			93.17 (48.81)	0.0281	91.31 (48.69)	0.0304	96.19 (48.85)	0.0245
Slope for knowledge retention			5.68 (3.36)	0.0452	5.95 (3.42)	0.041	5.43 (3.24)	0.0469
Goodness-of-Fit Statistics								
-2 Log Likelihood	6051.2		5736.6		5725.9		5428.3	
Akaike's Information Criterion	6055.2		5750.6		5739.9		5442.3	

Notes - Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO IMCI training. The intercept in Model 4 represents the baseline knowledge for the person who had no IMCI training, had SCL initial training in 2015/2016, were nurses, did not use smartphones, Setswana spoken most commonly, were discomfort with treatment of severe pneumonia, work in hospital, perception of frequency of resuscitation <=1 month, and did not complete a 6-month assessment.

Table 4 Models for Dehydration Sub-score Acquisition and Retention in Relation to Previous IMCI Training

	Model 1 (N = 679)		**Model 2 (N = 679)**		**Model 3 (N = 679)**		**Model 4 (N =655)**	
	γ (SE)	***p***	**γ (SE)**	***p***	**γ (SE)**	***p***	**γ (SE)**	***p***
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**IMCI training added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	26.37 (0.50)	<.0001	16.82 (0.77)	<.0001	16.77 (1.03)	<.0001	17.16 (2.24)	<.0001
Previous IMCI training (yes vs. no)					0.13 (1.54)	0.9304	1.06 (1.57)	0.5026
Location of work (Clinic or Health post vs. Hospital)							-2.24 (1.12)	0.0481
Location of work (Other vs. Hospital)							-1.65 (1.59)	0.3025
Profession status (Physician vs. Nurse)							7.21 (1.89)	0.0002
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.76 (1.00)	0.4473
English spoken most commonly (Yes vs. No)							0.71 (1.31)	0.5901
Comfortable with treatment of severe pneumonia (Agree vs. Disagree/Neutral)							-0.97 (1.01)	0.3396
Smartphone usage (Yes vs. No)							0.27 (0.90)	0.7676
Year of program (2014 vs. 2015 or 2016)							-0.19 (1.34)	0.8905
Had 6-month assessment (Yes vs. No)							1.04 (1.08)	0.3361
Rate of Change (slope for timepiece one)								
Knowledge acquisition			14.74 (0.91)	<.0001	14.73 (1.23)	<.0001	14.58 (1.29)	<.0001
Previous IMCI training (yes vs. no)					0.04 (1.83)	0.9843	0.12 (1.90)	0.9511
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.92 (0.26)	0.0005	-1.16 (0.38)	0.0023	-1.10 (0.39)	0.0055
Previous IMCI training (yes vs. no)					0.46 (0.52)	0.3795	0.39 (0.54)	0.4681
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	137.48 (8.57)	<.0001	66.13 (6.78)	<.0001	66.02 (6.78)	<.0001	65.42 (6.75)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	9.55 (4.98)	0.0275	53.95 (13.70)	<.0001	54.64 (13.77)	<.0001	42.28 (13.51)	0.0002
Slope for knowledge acquisition			55.47 (20.16)	0.003	56.40 (20.26)	0.0304	63.18 (20.97)	0.0013
Slope for knowledge retention			1.23 (1.10)	0.1322	1.28 (1.11)	0.1256	1.34 (1.12)	0.1159
Goodness-of-Fit Statistics								
-2 Log Likelihood	5310.7		5032.1		5025.9		4798.2	
Akaike's Information Criterion	5314.7		5046.1		5039.9		4812.2	

Notes - Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO IMCI training. The intercept in Model 4 represents the baseline knowledge for the person who had no IMCI training, had SCL initial training in 2015/2016, were nurses, did not use smartphones, Setswana spoken most commonly, were discomfort with treatment of severe pneumonia, work in hospital, perception of frequency of resuscitation <=1 month, and did not complete a 6-month assessment.

Table 5 Models for Pneumonia Sub-score Acquisition and Retention in relation to Previous IMCI Training

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =655)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**IMCI training added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	33.84 (0.60)	<.0001	26.23 (1.00)	<.0001	27.36 (1.34)	<.0001	28.31 (2.77)	<.0001
Previous IMCI training (yes vs. no)					-2.52 (2.00)	0.2113	-1.74 (1.94)	0.3711
Location of work (Clinic or Health post vs. Hospital)							-0.78 (1.39)	0.575
Location of work (Other vs. Hospital)							-6.09 (1.96)	0.0024
Profession status (Physician vs. Nurse)							10.20 (2.30)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							-0.16 (1.23)	0.8943
English spoken most commonly (Yes vs. No)							2.26 (1.59)	0.1568
Comfortable with treatment of severe pneumonia (Agree vs. Disagree/Neutral)							0.72 (1.25)	0.5655
Smartphone usage (Yes vs. No)							0.49 (1.10)	0.6574
Year of program (2014 vs. 2015 or 2016)							-3.06 (1.66)	0.0676
Had 6-month assessment (Yes vs. No)							2.02 (1.31)	0.1287
Rate of Change (slope for timepiece one)								
Knowledge acquisition			11.56 (1.09)	<.0001	9.76 (1.47)	<.0001	9.83 (1.48)	<.0001
Previous IMCI training (yes vs. no)					3.96 (2.18)	0.0717	3.65 (2.17)	0.096
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.42 (0.28)	0.1422	-0.21 (0.41)	0.6084	-0.34 (0.42)	0.4229
Previous IMCI training (yes vs. no)					-0.45 (0.57)	0.4384	-0.39 (0.55)	0.4829
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	151.45 (9.83)	<.0001	79.17 (8.46)	<.0001	79.08 (8.46)	<.0001	78.49 (8.22)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	25.91 (7.80)	0.0004	124.93 (21.90)	<.0001	124.51 (21.90)	<.0001	94.07 (19.96)	<.0001
Slope for knowledge acquisition			106.84 (27.75)	<.0001	104.01 (27.56)	<.0001	95.09 (26.71)	0.0002
Slope for knowledge retention			2.09 (1.43)	0.0713	2.17 (1.45)	0.0671	2.06 (1.33)	0.0617
Goodness-of-Fit Statistics								
-2 Log Likelihood	5424.9		5266.9		5257.3		4986.7	
Akaike's Information Criterion	5428.9		5280.9		5271.3		5000.7	

Notes - Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO IMCI training. The intercept in Model 4 represents the baseline knowledge for the person who had no IMCI training, had SCL initial training in 2015/2016, were nurses, did not use smartphones, Setswana spoken most commonly, were discomfort with treatment of severe pneumonia, work in hospital, perception of frequency of resuscitation <=1 month, and did not complete a 6-month assessment.

Figure 1:

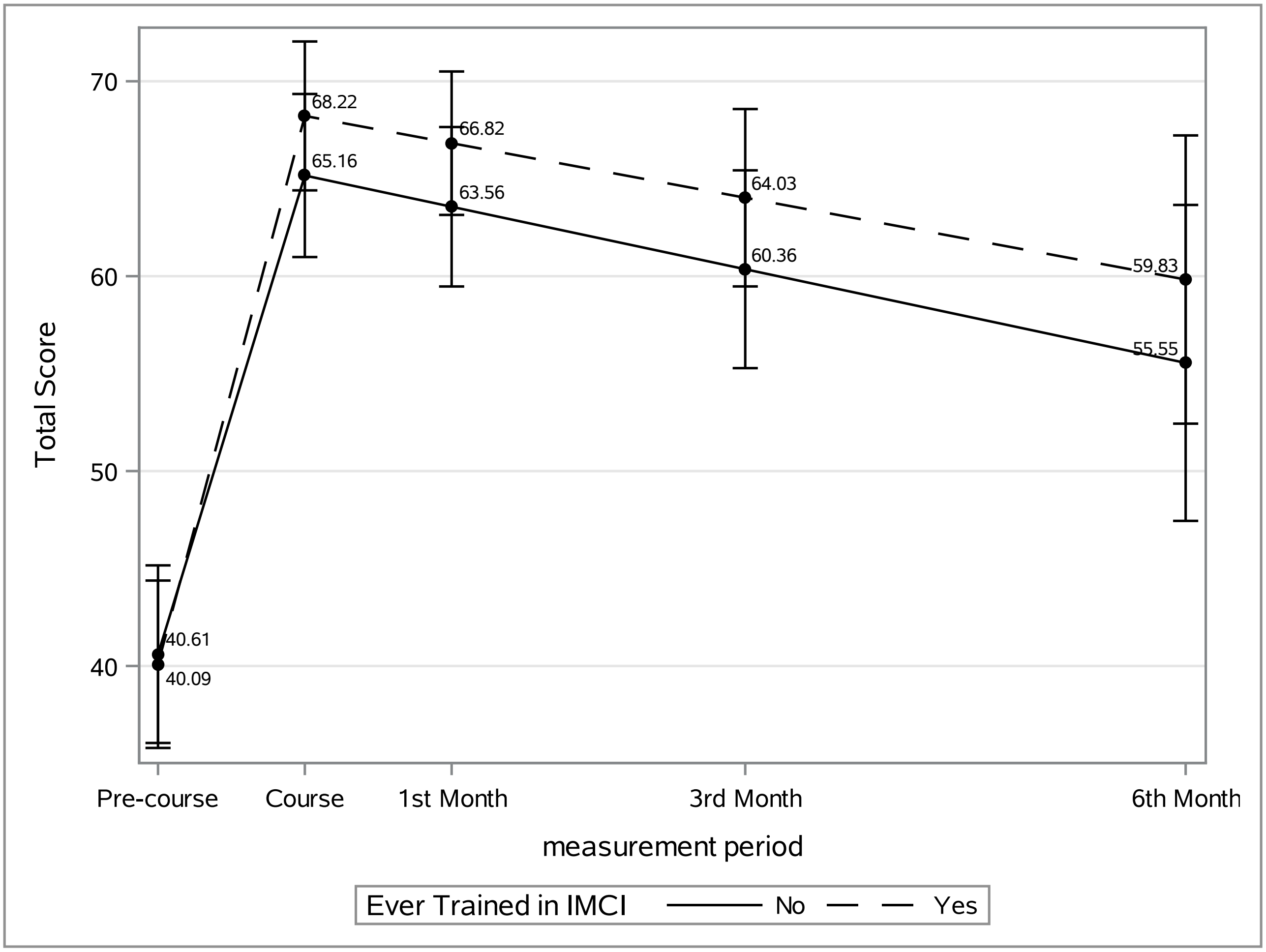
- Caption: Model-Based Marginal Total Score by IMCI Training over Time (adjusted)
- Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

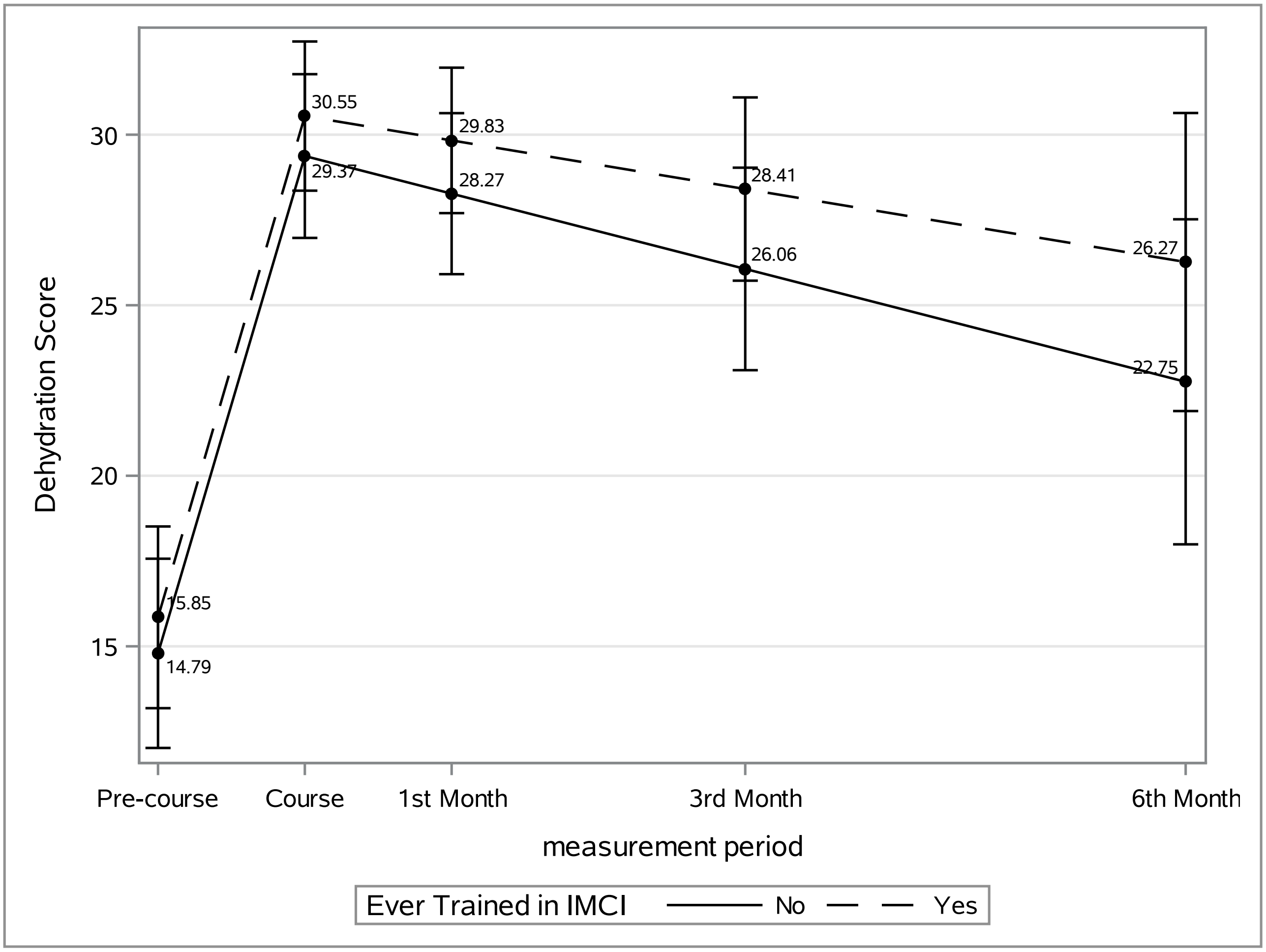
Figure 2:

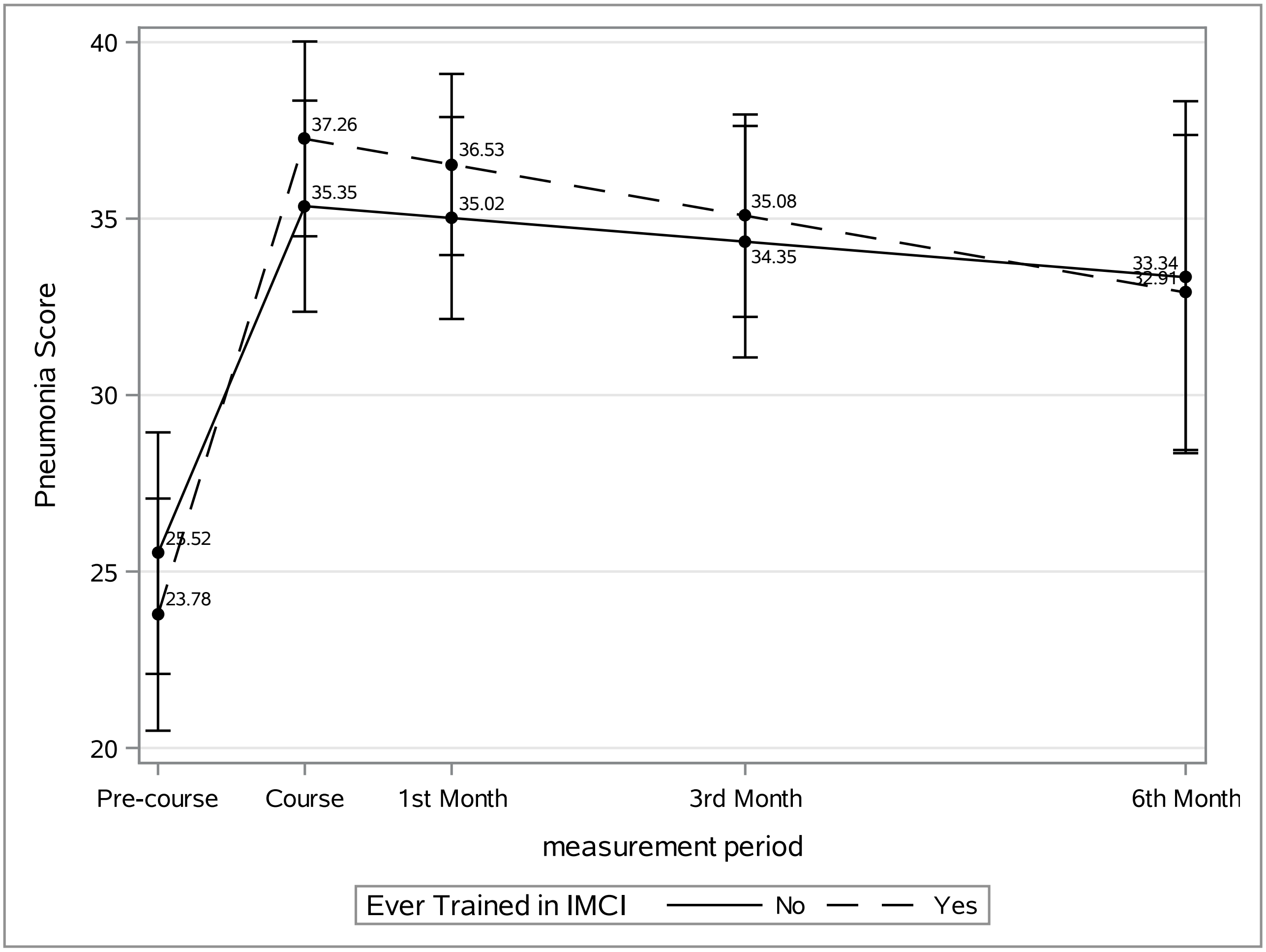
- Caption: Model-Based Dehydration Sub-Score by IMCI Training over Time (adjusted)
- Legend: Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

Figure 3:

- Caption: Model-Based Pneumonia Sub-Score by IMCI Training over Time (adjusted)
- Legend: Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment


Total Score
70
60
50
40
68.22
65.16
66.82
63.56
64.03
60.36
59.83
55.55
40.61
40.09
Pre-course
Course
1st Month
3rd Month
6th Month
measurement period
Ever Trained in IMCI
No
Yes


Dehydration Score
30
25
20
15
30.55
29.37
29.83
28.27
28.41
26.06
26.27
22.75
15.85
14.79
Pre-course
Course
1st Month
3rd Month
6th Month
measurement period
Ever Trained in IMCI
No
Yes


Pneumonia Score
40
35
30
25
20
37.26
35.35
36.53
35.02
35.08
34.35
33.34
32.91
25.52
23.78
Pre-course
Course
1st Month
3rd Month
6th Month
measurement period
Ever Trained in IMCI
No
Yes

Post-Hoc Testing/Sensitivity Analysis (Online Supplement):

Due to the significant loss of follow-up, we conducted a sensitivity analysis to examine if there was evidence of non-random missingness. To adjust for confounders, program year and work location was included in model as a priori. In addition, any student or course variable that was significantly different ($p<0.1$) between those completing 6-month follow-up and who did not, or had significantly different course assessment scores was included in the linear mixed model.

Variables considered potential confounders included in the sensitivity analysis included: year of initial training, degree of comfort with treatment of severe dehydration, ever previously trained in pediatric resuscitation, , ever previously trained in trauma resuscitation, ever previously trained in cardiopulmonary resuscitation, instructor mix, professional status, location of work, and perceived frequency of resuscitation > 1 month.

Overall, a strong and significant effect was seen with knowledge acquisition (b= +26.76, ±1.71, p <0.0001) (online supplement table B, Model 4), and there was significant loss of knowledge over time (b= -3.47 ±0.74 /month, p<.0001).

- Completing 6-month follow-up was not associated with baseline knowledge level (b=-2.81±3.29, p=0.3932), nor knowledge acquisition (b= +1.26 ±3.69, p= 0.7329), but a significant effect on knowledge retention (b= +3.03 ±0.88/month, p=0.0007).

- Dehydration sub scores had strong and significant effect was seen with knowledge acquisition (b= +14.68 ±1.10, p <0.0001), and strong and significant loss of knowledge over time (b= -1.56±0.45/month, p= 0.0006).

- Completing 6-month follow-up was not associated with baseline dehydration knowledge level (b=-1.69±2.10, p=0.4205), knowledge acquisition (b= +0.45±2.40, p=0.8529), nor knowledge retention (b= +0.84±0.54/month, p=0.118).

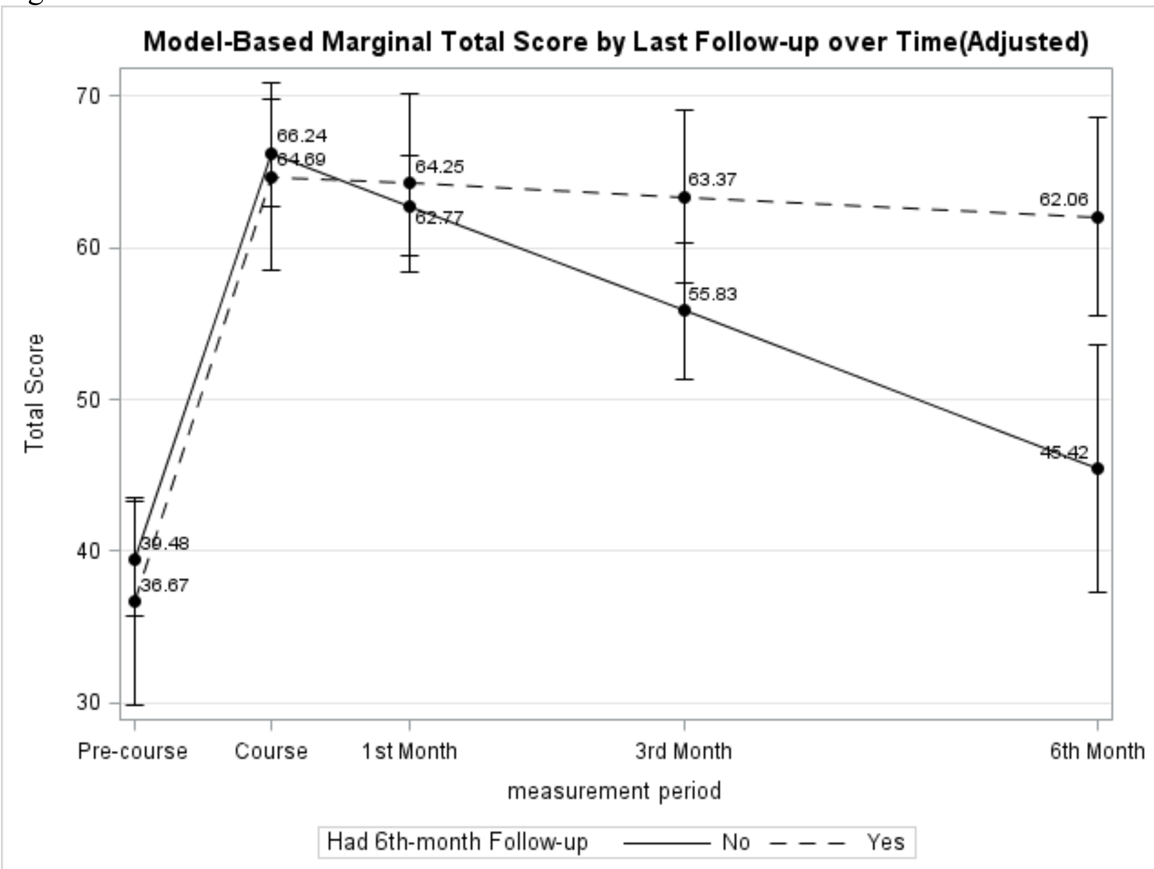
- Pneumonia sub scores had strong and significant effect was seen with knowledge acquisition (b= +12.07 ±1.27, p <0.0001), and significant loss of knowledge over time (b= -1.95 ±0.50/month, p<0.0001)
  - In the pneumonia sub score, completing 6-month follow-up was not associated with baseline knowledge level (b=-1.23±2.58), p=0.6345), nor knowledge acquisition (b= +0.81 ±2.76, p = 0.7683), but significant gain on retention (b= +2.24 ±0.6/month, p= 0.0003).

Table A: Provider Characteristics	Overall	Follow Up at 6 months	Lost to Follow up	p value
N	211	44	167	
Professional Status*		[n (%)]	[n (%)]	
Nurse	187 (90.8)	36 (19.3)	151 (80.7)	0.2038
Physician	19 (9.2)	6 (31.6)	13 (68.4)	
Location of work***				
Clinic or Health post	127 (61.1)	27 (21.3)	100 (78.7)	0.8260
Hospital	52 (25.0)	12 (23.1)	40 (76.9)	
Other	29 (13.9)	5 (17.2)	24 (82.8)	
Mobile phone**				
Smart	111 (53.1)	25 (22.5)	86 (77.5)	0.5791
Text and Voice only or no cell phone	98 (46.9)	19 (19.4)	79 (80.6)	
English spoken most commonly				
Yes	51 (24.2)	13 (25.5)	38 (74.5)	0.3492
No	160 (75.8)	31 (19.4)	129 (80.6)	
Perceived frequency of resuscitation > 1 month****				
Yes	138 (66.7)	27 (19.6)	111 (80.4)	0.4004
No	69 (33.3)	17 (24.6)	52 (75.4)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia				
Agree	147 (69.7)	33 (22.4)	114 (77.6)	0.3872
Disagree/Neutral	64 (30.3)	11 (17.2)	53 (82.8)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Dehydration.				
Agree	168 (79.6)	39 (23.2)	129 (76.8)	0.0952
Disagree/Neutral	43 (20.4)	5 (11.6)	38 (88.4)	
Resuscitation Success (perceived)****				
0-25%	84 (40.8)	15 (17.8)	69 (82.1)	0.4269
26-50%	32 (15.5)	5 (15.6)	27 (84.4)	
51-75%	37 (18.0)	8 (21.6)	29 (78.4)	
76-100%	53 (25.7)	15 (28.3)	38 (71.7)	
Previous Resuscitation Training				
Pediatric ****	23 (11.1)	8 (34.8)	15 (65.2)	0.0877
Neonatal *	21 (10.2)	4 (19.0)	17 (81.0)	1
Trauma *	21 (10.2)	1 (4.8)	20 (95.2)	0.0846
CPR ***	73 (35.1)	21 (28.8)	52 (71.2)	0.0158
Year of the program***				
2014	162 (77.9)	39 (24.1)	123 (75.9)	0.023
2015 or 2016	46 (22.1)	4 (8.7)	42 (91.3)	
Instructor Type***				

IFO	52 (25.0)	33 (63.5)	19 (36.5)	<.0001
LT70LF	96 (46.2)	4 (4.2)	92 (95.8)	
GT70LF	39 (18.7)	5 (12.8)	34 (87.2)	
LFO	21 (10.10)	1 (4.7)	20 (95.2)	

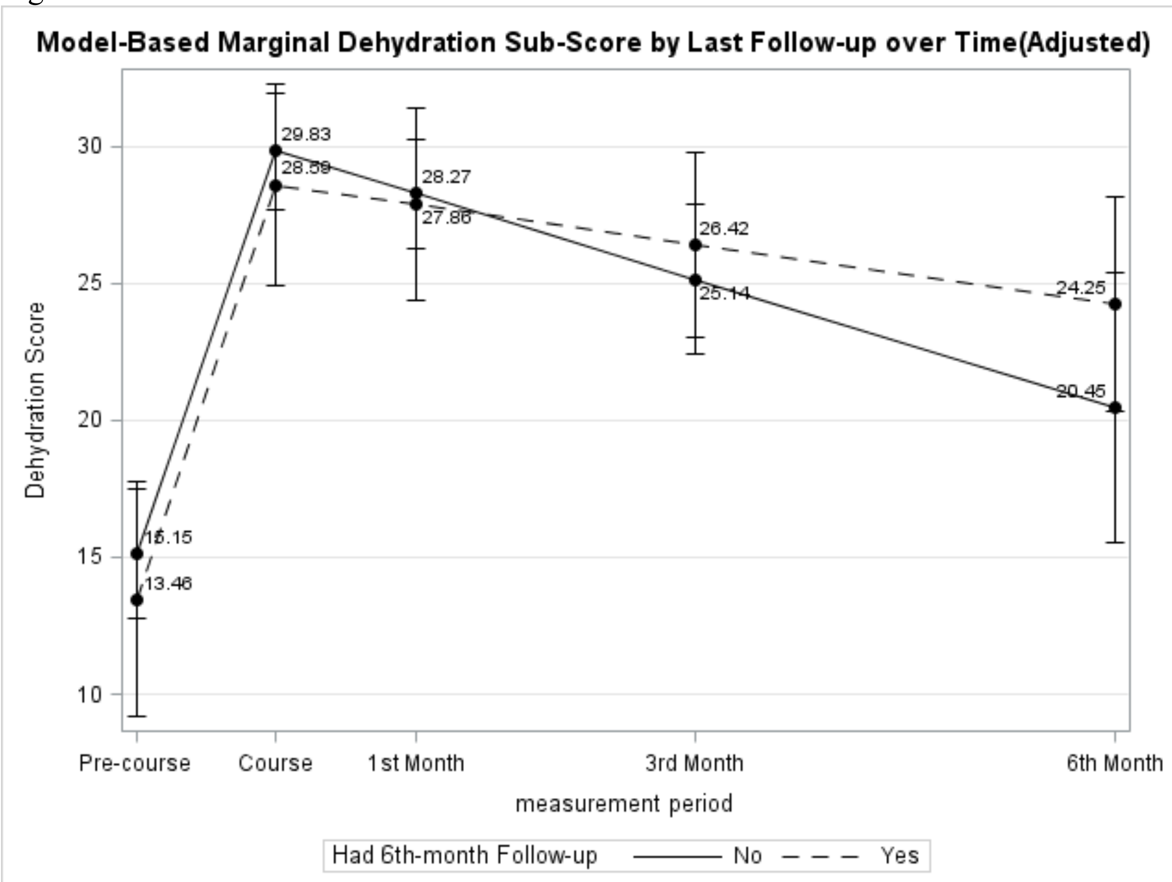
*5 participants did not report profession, previous neonatal or trauma resuscitation training.
** 2 did not report cellphone access
***3 did not report previous CPR training, location of work, year of training or instructor type
****4 did not report perceived frequency of resuscitation, resuscitation success (perceived), or previous pediatric resuscitation training.
Previous Pediatric Resuscitation = Pediatric Advanced Life Support, Emergency Triage Assessment and Treatment
Previous Neonatal Resuscitation = Neonatal Resuscitation Training, Helping Babies Breathe.
Previous CPR: Cardiopulmonary Resuscitation
Other includes hospital based (administrative/'other')

Figure A



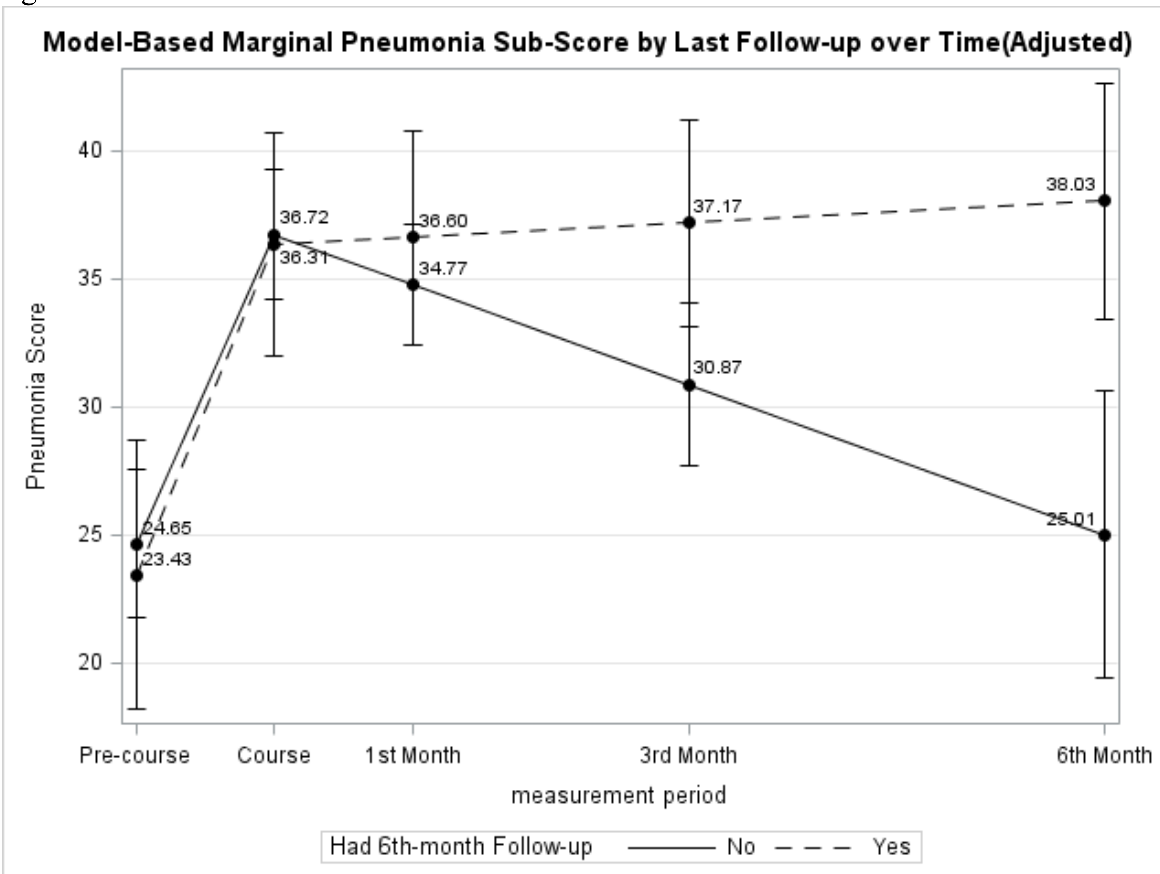
Plots were based on estimates of participants who received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, and perception of frequency of resuscitation >1 month.

Figure B



Plots were based on estimates of participants who received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, and perception of frequency of resuscitation >1 month.

Figure C



Plots were based on estimates of participants who received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, and perception of frequency of resuscitation >1 month.

Table B Models for total score acquisition and retention by whether or not having 6-month assessment

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =635)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**6th-month follow-up added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	60.20 (0.90)	<.0001	43.04 (1.32)	<.0001	43.00 (1.49)	<.0001	41.84 (3.95)	<.0001
Had 6-month assessment (yes vs. no)					0.27 (3.22)	0.9331	-2.81 (3.29)	0.3932
Location of work (Clinic or Health post vs. Hospital)							-1.96 (2.04)	0.3382
Location of work (Other vs. Hospital)							-8.24 (2.78)	0.0034
Profession status (Physician vs. Nurse)							19.00 (2.74)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.36 (1.71)	0.8339
Year of program (2014 vs. 2015/ 2016)							-4.18 (2.68)	0.1209
Comfortable with treatment for severe dehydration (Agree vs. Disagree/Neutral)							3.42 (1.95)	0.0807
PALS/ETAT training ever (Yes vs. No)							-2.31 (2.82)	0.4137
Trauma training ever (Yes vs. No)							5.30 (2.76)	0.0555
CPR training ever (Yes vs. No)							2.48 (1.92)	0.1979
Instructor type (GT70LF vs. LT70LF)							2.06 (2.23)	0.3581
Instructor type (IFO vs. LT70LF)							4.49 (2.32)	0.054
Instructor type (LFO vs. LT70LF)							3.63 (3.73)	0.3322
Rate of Change (slope for timepiece one)								
Knowledge acquisition			26.12 (1.46)	<.0001	27.05 (3.22)	<.0001	26.76 (1.71)	<.0001
Had 6-month assessment (yes vs. no)					0.67 (3.49)	0.8472	1.26 (3.69)	0.7329
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.98 (0.37)	0.0091	-3.87 (0.73)	<.0001	-3.47 (0.74)	<.0001
Had 6-month assessment (yes vs. no)					3.57 (0.86)	<.0001	3.03 (0.88)	0.0007
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	399.07 (25.19)	<.0001	194.00 (16.03)	<.0001	187.54 (15.60)	<.0001	182.82 (15.69)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	41.59 (16.39)	0.0056	162.06 (38.74)	<.0001	170.06 (38.76)	<.0001	83.34 (32.81)	0.0055
Slope for knowledge acquisition			103.11 (43.88)	0.0094	108.67 (43.48)	0.0062	114.16 (44.51)	0.0052
Goodness-of-Fit Satistics								
-2 Log Likelihood	6051.2		5752.4		5720		5222.2	
Akaike's Information Criterion	6055.2		5760.4		5728		5230.2	

Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO 6-month assessment. The intercept in Model 4 represents the baseline knowledge for the person who had no 6-month assessment, had SCL initial training in 2015/2016, was nurses, discomfort with treatment of severe dehydration, worked in hospital, perception of frequency of resuscitation <=1 month, had no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, and course taught by less than 70% local instructors.

Table C Models for dehydration subscore acquisition and retention by whether or not having 6-month assessment

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =635)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**6th-month follow-up added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	26.37 (0.50)	<.0001	16.84 (0.77)	<.0001	16.75 (0.87)	<.0001	13.36 (2.37)	<.0001
Had 6-month assessment					0.43 (1.87)	0.8189	-1.69 (2.10)	0.4205
Location of work (Clinic or Health post vs. Hospital)							-1.24 (1.21)	0.3075
Location of work (Other vs. Hospital)							-1.23 (1.65)	0.4562
Profession status (Physician vs. Nurse)							5.98 (1.63)	0.0003
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.73 (1.02)	0.4726
Year of program (2014 vs. 2015 or 2016)							0.52 (1.60)	0.7453
Comfortable with treatment of severe dehydration (Agree vs. Disagree/Neutral)							1.78 (1.16)	0.1251
PALS/ETAT training ever (Yes vs. No)							-0.93 (1.66)	0.5765
Trauma training ever (Yes vs. No)							1.12 (1.64)	0.496
CPR training ever (Yes vs. No)							2.34 (1.14)	0.0413
Instructor type (GT70LF vs. LT70LF)							0.24 (1.34)	0.8579
Instructor type (IFO vs. LT70LF)							3.56 (1.37)	0.0098
Instructor type (LFO vs. LT70LF)							3.27 (2.24)	0.1462
Rate of Change (slope for timepiece one)								
Knowledge acquisition			14.64 (0.92)	<.0001	14.78 (1.06)	<.0001	14.68 (1.10)	<.0001
Had 6-month assessment					0.93 (2.23)	0.6763	0.45 (2.40)	0.8519
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.76 (0.22)	0.0008	-1.68 (0.44)	0.0002	-1.56 (0.45)	0.0006
Had 6-month assessment					1.05 (0.52)	0.0448	0.84 (0.54)	0.118
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	137.48 (8.56)	<.0001	69.71 (5.77)	<.0001	69.34 (5.77)	<.0001	67.02 (5.79)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	9.55 (4.98)	0.0275	50.30 (13.21)	<.0001	51.24 (13.28)	<.0001	44.73 (13.22)	0.0004
Slope for knowledge acquisition			54.41 (17.51)	0.0009	55.99 (17.64)	0.0007	64.92 (18.70)	0.0003
Goodness-of-Fit Statistics								
-2 Log Likelihood	5310.7		5048.1		5033.8		4624.3	
Akaike's Information Criterion	5314.7		5056.1		5041.8		4632.3	

Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO 6-month assessment. The intercept in Model 4 represents the baseline knowledge for the person who had no 6-month assessment, had SCL initial training in 2015/2016, was nurses, discomfort with treatment of severe dehydration, worked in hospital, perception of frequency of resuscitation <=1 month, had no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, and course taught by less than 70% local instructors.

Table D Models for pneumonia subscore acquisition and retention by whether or not having 6-month assessment

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =635)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**6th-month follow-up added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	33.84 (0.60)	<.0001	26.22 (1.00)	<.0001	26.27 (1.13)	<.0001	27.85 (2.89)	<.0001
Had 6-month assessment					-0.18 (2.44)	0.9416	-1.23 (2.58)	0.6345
Location of work (Clinic or Health post vs. Hospital)							-0.32 (1.48)	0.831
Location of work (Other vs. Hospital)							-6.87 (2.01)	0.0007
Profession status (Physician vs. Nurse)							11.71 (1.98)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							-0.18 (1.24)	0.8874
Year of program (2014 vs. 2015 or 2016)							-4.33 (1.94)	0.0268
Comfortable with treatment of severe dehydration (Agree vs. Disagree/Neutral)							1.62 (1.41)	0.2502
PALS/ETAT training ever (Yes vs. No)							-1.31 (2.03)	0.5183
Trauma training ever (Yes vs. No)							3.78 (1.99)	0.0586
CPR training ever (Yes vs. No)							0.30 (1.39)	0.8272
Instructor type (GT70LF vs. LT70LF)							1.82 (1.63)	0.2661
Instructor type (IFO vs. LT70LF)							1.10 (1.67)	0.5108
Instructor type (LFO vs. LT70LF)							0.61 (2.72)	0.823
Rate of Change (slope for timepiece one)								
Knowledge acquisition			11.43 (1.09)	<.0001	12.24 (1.25)	<.0001	12.07 (1.27)	<.0001
Had 6-month assessment					-0.24 (2.62)	0.9282	0.81 (2.76)	0.7683
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.23 (0.25)	0.3628	-2.24 (0.49)	<.0001	-1.95 (0.50)	<.0001
Had 6-month assessment					2.57 (0.58)	<.0001	2.24 (0.60)	0.0003
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	151.45 (9.83)	<.0001	88.40 (7.45)	<.0001	85.15 (7.22)	<.0001	84.62 (7.36)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	25.91 (7.80)	0.0004	115.75 (21.54)	<.0001	119.92 (21.59)	<.0001	84.93 (19.55)	<.0001
Slope for knowledge acquisition			93.09 (24.26)	<.0001	94.42 (23.92)	<.0001	93.07 (24.38)	<.0001
Goodness-of-Fit Statistics								
-2 Log Likelihood	5424.9		5270		5239.9		4806.4	
Akaike's Information Criterion	5428.9		5278		5247.9		4814.4	

Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO 6-month assessment. The intercept in Model 4 represents the baseline knowledge for the person who had no 6-month assessment, had SCL initial training in 2015/2016, was nurses, discomfort with treatment of severe dehydration, worked in hospital, perception of frequency of resuscitation <=1 month, had no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, and course taught by less than 70% local instructors.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	3
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	3
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	#3	State specific objectives, including any prespecified hypotheses	6
Study design	#4	Present key elements of study design early in the paper	7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	6
	#6b	For matched studies, give matching criteria and number of exposed and	6

		unexposed	
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	7
Bias	#9	Describe any efforts to address potential sources of bias	6,9
Study size	#10	Explain how the study size was arrived at	6
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	6-9
	#12b	Describe any methods used to examine subgroups and interactions	6-9
	#12c	Explain how missing data were addressed	8
	#12d	If applicable, explain how loss to follow-up was addressed	9
	#12e	Describe any sensitivity analyses	9
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	10
	#13b	Give reasons for non-participation at each stage	9
	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	10
	#14b	Indicate number of participants with missing data for each variable of interest	12
	#14c	Summarise follow-up time (eg, average and total amount)	12

Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	10-12
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
	#16b	Report category boundaries when continuous variables were categorized	10-12
	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	10-12
Key results	#18	Summarise key results with reference to study objectives	13
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	16
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	16
Generalisability	#21	Discuss the generalisability (external validity) of the study results	16
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

 This checklist was completed on 05. February 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

Knowledge acquisition and retention following Saving Children’s Lives course for healthcare providers in Botswana: a longitudinal cohort study

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Primary Subject Heading:	Medical education and training
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Title: Knowledge acquisition and retention following Saving Children's Lives course for healthcare providers in Botswana: a longitudinal cohort study

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Short Title: 'Saving Children's Lives' Increases Provider Knowledge

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Abbreviations: serious childhood illness (SCI), Saving Children's Lives (SCL), abbreviated high intensity training (aHIT), Integrated Management of Childhood Illness (IMCI), World Health Organization (WHO), low and middle-income countries (LMICs), international faculty (IF), local faculty (LF), international faculty only (IFO), < 70% local faculty (LT70LF), > 70% local faculty (GT70LF), local faculty only (LFO)

Table of Contents Summary:
Saving Children's Lives training significantly increases healthcare provider knowledge to care for seriously ill children and is highly relevant to middle-income country health systems.

Contributors' Statement:
Dr Meaney conceptualized and designed the study, carried out the initial analyses, designed the data collection instruments, drafted the initial manuscript, and critically reviewed the manuscript for important intellectual content.
Mr Setlhare designed the data collection instruments, collected data, carried out the initial analyses, and critically reviewed the manuscript for important intellectual content.
Dr Joyce collected data, carried out the initial analyses, and critically reviewed the manuscript for important intellectual content.
Mrs Kgosiesiele, Dr Kalenga and Jibril conceptualized and designed the study, coordinated and supervised data collection.
Dr Kloeck coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content.
Drs Mensinger, Zhang, and Smith made substantial contributions to analysis and interpretation of data, and critically reviewed the manuscript for important intellectual content.
Dr Mazhani, deCaen and Steenhoff conceptualized and designed the study, and critically reviewed the manuscript for important intellectual content.
All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Word Count: 3906

Keywords: Medical Education & Training, Accident & Emergency Medicine, Paediatric Intensive & Critical Care, Primary Care, Community Child Health

Data Sharing Statement: copy of the dataset is available by emailing the corresponding author (meaneypa@stanford.edu)

Abstract

Objectives

Millions of children die every year from serious childhood illnesses. Most deaths are avertable with access to quality care. Saving Children's Lives (SCL) includes an abbreviated high intensity training (SCL-aHIT) for providers who treat serious childhood illnesses. The objective of this study was to examine the impact of SCL-aHIT on knowledge acquisition and retention of providers.

Setting:

76 participating centers who provide primary and secondary care in Kweneng District, Botswana.

Participants:

Doctors and nurses expected by the District Health Management Team to provide initial care to seriously ill children, completed SCL-aHIT between January 2014 and December 2016, submitted demographic data, course characteristics, and at least one knowledge assessment.

Methods:

Retrospective, cohort study. Planned and actual primary outcome was adjusted acquisition (change in total knowledge score immediately after training) and retention (change in score at 1, 3 and 6 months), secondary outcomes were pneumonia and dehydration subscores. Descriptive statistics and linear mixed models with random intercept and slope were conducted. Relevant IRBs approved this study.

Results:

211 providers had data for analysis. Cohort was 91% nurses, 61% clinic/health-post based, and 45% pre-trained in Integrated Management of Childhood Illness (IMCI). A strong effect of SCL-aHIT was seen with knowledge acquisition ($+24.56\pm1.94$, $p < 0.0001$), and loss of retention was observed (-1.60 ± 0.67/month, $p=0.018$). IMCI training demonstrated no significant effect on acquisition ($+3.58\pm2.84$, $p=0.211$ or retention ($+0.20\pm0.91$/month, $p=0.824$) of knowledge. On average, nurses scored lower than physicians (-19.39 ± 3.30, $p < .0001$). Lost to follow-up had a significant impact on knowledge retention (-3.03 ± 0.88/month, $p=0.0007$).

Conclusions:

Abbreviated high intensity training for care of the seriously ill child significantly increased provider knowledge and loss of knowledge occurred over time. IMCI training did not significantly impact overall knowledge acquisition nor retention, while professional status impacted overall score and loss to follow-up impacted retention.

Strengths and limitations of this study

- This is the first longitudinal cohort study to describe the impact of an abbreviated high-intensity training for serious childhood illness on doctors and nurses working in community clinics and district hospitals in a middle-income country.
- Data collected allowed the examination of demographic and training factors that impact training with knowledge acquisition and retention.
- There was significant loss to follow-up during the study period, and those doctors and nurses had significantly increased loss of knowledge over time.
- Outcomes are limited to provider knowledge, not actual or reported performance.

Introduction

Each year, severe pneumonia, shock from diarrheal dehydration and sepsis are responsible for 25% of 5.1 million child deaths that occur worldwide.[1,2] Over 1 million children die each year due to lack of effective, low-cost interventions being available and utilized appropriately.[3] Access to quality healthcare is a global challenge, and timely and effective treatment for pneumonia and diarrhea are essential components.[4-6]

A child mortality audit in Botswana between 2011-2013 demonstrated that 46% of pediatric in-hospital deaths were due to severe pneumonia, diarrheal dehydration and sepsis.[7] 33% of in-hospital pediatric deaths occurred within the first 24 hours, an indication that children arrived critically ill. 26% of all in-hospital deaths were considered avoidable, with an average of 2.6 modifiable factors contributing to each death.[7] Delayed or inadequate recognition and treatment of serious illness were major modifiable factors, and over 50% of factors were attributed to provider performance.

Healthcare providers in Botswana are trained to care for ill children using the Integrated Management of Childhood Illness (IMCI). IMCI is a training program endorsed by the World Health Organization (WHO) to train healthcare providers to care for children in low and middle-income countries (LMICs). However, studies have demonstrated that after health providers receive IMCI training, one-third to one half of seriously ill children are not identified and do not receive correct treatment for potentially life-threatening conditions.[8-10]

Saving Children's Lives (SCL) program is a collaboration between the Botswana Ministry of Health, the University of Botswana, Botswana University of Pennsylvania Partnership, Children's Hospital of Philadelphia Center for Global Pediatric Critical Care, and the American Heart Association to improve the quality of care for seriously ill or injured children. Saving Children's Lives abbreviated high-intensity training (SCL-aHIT) is a 2-day training focused on the knowledge and skills a healthcare provider needs to optimally recognize and initiate stabilizing treatment in the community clinic, primary or district hospital setting.

We hypothesized that SCL-aHIT would lead to significant knowledge acquisition and retention by healthcare providers. We also hypothesized that IMCI training would not have significant impact on knowledge acquisition or retention. Further, we hypothesized that provider, training or work environment characteristics may impact knowledge acquisition and retention. Finally, we hypothesized that SCL-aHIT may impact knowledge of pneumonia and diarrhea scores may have differential acquisition and retention.

Methods:

Study design:

This retrospective cohort study was conducted to examine the impact of district-level SCL-aHIT on provider knowledge in Kweneng District, Botswana. All components of the SCL program were active during the study period. Data was extracted from the SCL administrative database and included participant demographics and knowledge assessments. Our primary outcome was total score acquisition with secondary outcomes of total score retention, and pneumonia and diarrhea subscores of both acquisition and retention.

Setting:

Kweneng District, Botswana, has a population of 304,000, with 83% people living within 8 km of a health facility (100% within 15km).[11-13] There is one district hospital, two primary hospitals, nine clinics with beds, and sixty-four health posts and clinics without beds in the district. The estimated doctor/population ratio is 1:550 and nurse/population ratio of 1:80.

Cohort Description:

Cohort consisted of a convenience sample of physicians and nurses from community clinics, health posts, primary and district hospitals. Providers were identified for training by the Kweneng District Health Management team based on if they were expected to provide initial stabilizing care to seriously ill children in their position. All subjects who participated in SCL-aHIT, completed demographic data and at least one knowledge assessment were eligible for inclusion. To minimize selection bias, follow-up assessments were attempted all providers identified in Kweneng district completed training.The SCL implementation team attempted to follow-up with participants of the training sessions in person or by phone. There were two attempts to complete the assessment at each time point for all course participants. More attempts were not possible due to program limitations.

Saving Children's Lives

The SCL program employs 5 major implementation strategies:

Implementation Strategy 1: Abbreviated High-Intensity In-Service Training:

SCL-aHIT is a contextualized version of the American Heart Association's Pediatric Emergency Assessment Recognition and Stabilization program. The contextualization process and initial training program has been described previously.[14] It is a combination of didactics, skills stations and simulated patient scenarios. To increase peer to peer learning and instructor situational awareness, didactics and final exam employed audience response software. While Rowe et al defined high intensity training as having a duration > 5 days which included interactive sessions (e.g. role play),[15] we defined abbreviated high intensity training (aHIT) as having interactive sessions but with a training duration < 5 days.

Implementation Strategy 2: Serial Facility Readiness Assessments:

The implementation team conducted bi-monthly Facility Readiness Assessments (FRA). The FRA is a focused inventory of personnel, equipment, and supplies relevant to treatment of seriously ill or injured children who present to clinics, health posts, or wards (hospitals). Estimated time to completion was one hour, and findings were immediately reported to the on-duty leadership, active issues reviewed, and solutions identified.

Implementation Strategy 3: Longitudinal Provider Knowledge Assessment

The knowledge assessment is a 6-item multiple-choice questionnaire was administered pre SCL-aHIT training, immediately following, and at one-, three-, and six- months. The assessment targeted to basic content regarding recognition and treatment of severe dehydration and moderate-severe pneumonia. Question types include 'select all that apply' and single best answer. Correct volume and rate of fluid administration for severe dehydration were consistent with current WHO and PALS guidelines. Choice of antibiotics for pneumonia was dependent on reported location of work and aligned with national guidelines.

Implementation Strategy 4: Bi-directional Active Feedback between Front-Line Providers and Health System Leadership.

The implementation team actively reported to health system leadership biannually and received feedback on program implementation strategies (training, facility readiness, and provider knowledge). Reports were conducted in person with District Health Management Team (DHMT) leadership (District Hospital Superintendent, Matron, and Chief Medical Officer) as well as Ministry of Health (Deputy Permanent Secretary of Clinical Services, Public Health, Permanent Secretary to the Minister of Health). These results, as well as the feedback from health system leadership, were reported back to the instructor group biannually at instructor "Bootcamps".

Implementation Strategy 5: Development and maintenance of a clinically relevant instructor core.

Instructor candidates were identified by instructors based on course performance, interest in subject matter, and interpersonal skills. After receiving approval from the DHMT, instructor candidates underwent a two-day instructor training focused on adult learning strategy, simulated patient scenario facilitation, and roles and responsibilities of being an active instructor. Then, they were monitored with structured feedback by senior SCL faculty for a minimum of two courses.

Outcomes

Data extracted from the SCL administrative database for analysis include self-reported provider demographics and serial knowledge assessment responses. Total and subscores were treated as continuous variables (potential range from 0-100). Provider demographics included: professional status, work location, type of personal mobile phone (smart vs other), language most commonly spoken, IMCI subtypes (time since training, training duration - short vs long), other previous resuscitation training, perception of resuscitation, and course multiple choice question (MCQ) score. A smart phone was defined as a mobile phone that had applications, access to internet and email. As SCL-aHIT employed audience response software as an education tool, the SCL program tracked smartphone ownership as a surrogate for comfort with technology to monitor possible impact on knowledge acquisition. The SCL program was initiated using highly experienced pediatric resuscitation education experts and transitioned to newly trained local instructors during the study period. To control for confounding due top variation in instructor experience, training characteristics included year of training and instructor mix. We defined the instructor mix of the initial training to be of four types: international faculty only (IFO), < 70% local faculty (LT70LF), > 70% local faculty (GT70LF), and local faculty only (LFO). We also defined training by the year initial SCL training was conducted: Jan 1-Dec 31 for 2014 (IF led, full program support), 2015 (LF led, high degree of IF supervision, full program support), and 2016 (LF led, minimal IF supervision, minimal program support).

Statistical Approach:

The statistical analysis was performed using SAS software, version 9.4. We conducted exploratory analyses to test for potential confounding between IMCI training and knowledge acquisition and retention. Means and standard deviations were presented for continuous variables, while frequency and percent were presented for discrete variables. Difference in participant or course characteristics between IMCI and non-IMCI groups were tested with Chi-square test for discrete variables. Difference in immediate post-training assessment score among participant or course characteristics were tested with independent-samples t-tests (Professional Status, English spoken most commonly, Perceived frequency of resuscitation > 1 month, I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia/ Severe Dehydration, Year of the program, Previous Resuscitation Training, Smart phone usage,) or one-way ANOVA (Location of work, Resuscitation Success (perceived), Instructor Type), as appropriate.

To answer the study's primary hypothesis, that participation in the SCL training would lead to significant increases in knowledge from baseline to post-course assessments and that the knowledge would be retained over the study period, we used a linear mixed model approach.

Best model fit was achieved with two linear segments, with baseline to immediate post-training as the first segment (knowledge acquisition), and immediate post-training to 6-month follow-up as the second segment (knowledge retention). Random intercepts were fit to allow for subject-specific baseline scores and random slopes were fit to the initial piece-wise segment to allow for subject-specific knowledge acquisition scores, as well as the second piece-wise segment to allow for subject-specific knowledge retention. The first model fit was the unconditional means model which includes only the random intercept. Model 2 was the unconditional growth model which included the fixed effects for each time segment, the random intercept, and the random slope for time segment 1 and 2. We show the proportion of variance in knowledge change over time that is explained by the complete Knowledge Assessment at one-, three-, and six- months after SCL-aHIT training (and subsequently by IMCI training and then the covariates) by examining the decrease in the within person residual variance from one model to the next. To answer hypothesis 2, Model 3 adds IMCI training to the unconditional growth equation. The main effect of IMCI assessed the difference in baseline knowledge level between the IMCI versus non-IMCI group. An interaction effect between previous IMCI training and the piece-wise time effects was also added into the model to assess whether IMCI training enhanced or diminished knowledge acquisition and/or retention. Model 4 presents the confounder adjusted model. Several covariates were included in this model a priori (year of training, location of work). To maintain a relatively parsimonious model yet still use a conservative cut-off for issues of confounding, we retained any variable that was significantly different between IMCI and non-IMCI participants or had significantly different course assessment scores in bivariate analysis ($p \leq 0.10$). To evaluate for non-random loss of follow-up (non-response bias), we conducted a sensitivity analysis that involved creating a variable for those missing 6-month assessments and those with 6-month assessment. Since these analyses revealed patterned missingness (dropouts had lower knowledge retention), we added this variable as a fixed factor to further control for loss-to-follow-up. We performed model diagnostics including testing for multivariate normality of residuals and testing for linearity of the trend in each time segment. Multicollinearity was assessed with Pearson correlation coefficient ($r<0.8$) among the potential confounders.

Ethics/IRB Considerations,:

We used the STROBE cohort checklist when writing our report.[16] The study was approved with a waiver of informed consent by the ethics boards of the Botswana Ministry of Health and the University of Pennsylvania.

Patient and Public Involvement statement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Results:

Description of cohort

Between January 2014 and December 2016, 211 providers had data available for analysis. 91% (187) were nurses, and 61% (127) were clinic/health post based and 25% (52) hospital based (Table 1). 98% (206) of providers had a mobile phone and 53% (111) reported owning a smart phone. 24% reported English was the most commonly used language. 67% self-reported that they resuscitated a seriously ill child at least once a month, and 30% and 20% of participants were not comfortable with the initial steps of stabilizing a child with severe pneumonia or diarrhea, respectively. 41% (84) of providers perceived resuscitation to be successful in less than 25% of cases where they work. Only 45% (95) reported previous IMCI training. Of providers with previous IMCI training, 74% (70) reported that the duration of IMCI training was less than 7 days (Table 2). 38 (40%) received IMCI training > 5 years ago and 32 (34%) < 2 years ago. Pediatric, neonatal or trauma resuscitation training was less than 12%, while 35% (73) had received CPR training. 78% (162) of participants received training in 2014, while 29% (60) were taught by an instructor group with 70% local instructors or only local instructors.

Sensitivity Analysis

To determine whether there were biases due to loss to follow-up, we created two groups: one group that had 6-month follow-up score and one group that did not have 6-month follow-up. We compared the acquisition of knowledge trajectory and retention of knowledge trajectory to ensure they were similar. Analysis showed differences in knowledge retention between the groups: the group with 6-month follow-up did not have a significantly better knowledge acquisition (+1.26, se=3.69, p=0.7329), but demonstrated significantly better retention

(+3.03/month, se=0.88, p=0.0007). To control for this bias, we entered this variable into the confounder-adjusted piecewise regression models described below (Model 4, Tables 3, 4, and 5). See Supplementary Table and Figures for results of the sensitivity analysis.

Description of Model

The assumption of multivariate normality was adequately met. Linearity was satisfied within each time segment. No multi-collinearity issue was found. Covariates included in the final model included: year of initial training, professional status, smart phone usage, language spoken most commonly, degree of comfort with treatment of severe pneumonia, location of work, perceived frequency of resuscitation, and presence/absence of 6-month follow-up.

A strong and significant main effect was seen for knowledge acquisition due to SCL-aHIT (time: pre to post) (b= +24.56 ±1.94, p<.0001), and loss of knowledge over time (b= -1.60 ±0.67/month, p=0.018). The proportion of variance in total scores knowledge change over time explained by the SCL education was 56.17% (R^2, Table 3). For dehydration subscores, a strong and significant main effect was seen for both knowledge acquisition (b=+14.58 ±1.29, p <0.001), and loss of knowledge over time (b= -1.10 ±0.39/month, p=0.0055). The proportion of variance in dehydration subscores knowledge change over time explained by the SCL education was 51.90% (R^2, Table 4). For pneumonia subscores, a strong and significant main effect was also seen for knowledge acquisition (b= +9.83 ±1.48, p <0.001), and no significant change in knowledge over time (b= -0.34 ±0.42/month, p=0.4229). The proportion of variance in pneumonia subscores knowledge change over time explained by the SCL education was 47.73% (Table 5)

To test the second hypothesis, IMCI training had no effect on knowledge at baseline (b=-0.52 ±2.45, p=0.834), knowledge acquisition (b=+3.58 ±2.84, p=0.211), knowledge retention (b=+0.20 ±0.91/month, p=0.824), for total scores. IMCI training explained 0.07% of additional variance in total score change. As for dehydration subscores, IMCI training had no effect on knowledge at baseline (b=+1.06±1.57, p=0.5026) knowledge acquisition (b= +0.12 ±1.90, p=0.9513), or knowledge retention (b= +0.39 ±0.54/month, p=0.4681). IMCI training explained 0.17% of additional variance in dehydration score change. For pneumonia subscores, IMCI training had no effect on knowledge at baseline (b=-1.74±1.94, p=0.3711)There was no difference in knowledge acquisition (b=3.65±2.17, p=0.096) or knowledge retention (b= -0.39 ±0.55/month, p=0.4829). IMCI training explained 0.11% of additional variance in pneumonia score.

Our final hypothesis was examined in the confounder-adjusted models (see Model 4 in Tables 3, 4, and 5). On average, nurses scored significantly lower than physicians at all time points: (b= -19.39 ±3.30, p <.0001) on total score, (b = -7.21±1.89, p=0.0002) on dehydration sub-score, and (b= -10.20±2.30, p<.0001) on pneumonia sub-score. Compared to those who worked in hospitals, participants who worked in clinics/health posts scored significantly worse on dehydration: (b= -2.24±1.12, p=0.0481). Perceived frequency of resuscitation, language, perceived comfort with treatment of pneumonia, smart phone usage, year of training and completeness of follow-up had no significant effect on total scores or the dehydration or pneumonia subscores.

Model-based mean scores for each assessment were calculated based on populations that represented the majority of the cohort: those who had SCL initial training in 2014, were nurses, used smartphones, spoke non-English most commonly, were comfortable treating of severe pneumonia, worked in clinic/health post, reported frequency of resuscitation >1/month, and did not complete a 6-month assessment were plotted (Figure 1-3).

Discussion:

This study demonstrates for the first time that SCL-aHIT significantly increases provider knowledge acquisition in the recognition and treatment of serious childhood illness. This is the largest study to our knowledge to report knowledge retention outcomes of providers who care for seriously ill children outside of academic centers in a low or middle income country. While previous IMCI training did not decrease knowledge acquisition, professional status and completing follow up assessments impacted scores significantly. There was significant loss to follow-up during the study period, and while the adjusted model demonstrated worse knowledge retention than those who completed 6-month follow-up, we are limited in our ability to draw strong conclusions regarding knowledge the true rate of loss of retention.

This increase in knowledge may be due to the characteristics of training, and our study is consistent with previous studies that demonstrate high intensity training being the most effective single implementation strategy to improve healthcare worker performance.[15,17] Rowe et al found that high intensity training had the greatest median training effect (11, IQR 8-15) compared to low-intensity training only (8, IQR 2-22), supervision (8, IQR 3-17), group problem solving (8, IQR 6-21), regulation/governance (5, IQR -1-20) or job aids (-3, IQR -7-+7). This is a similar increase Tusiyenge et al found when examining pediatric resuscitation knowledge acquisition and retention of final year medical students after a high-intensity training in an academic referral hospital setting in Malawi.[18] Further, the high impact of an abbreviated (2-day) high-intensity training is notable as shortened (5-10 day) IMCI training has been associated with a 2 to 16-point loss of treatment effect over standard (11-day) training.[9] While SCL-aHIT demonstrated a larger effect than the range in the systematic review, our outcomes were limited to knowledge assessment and the difference in magnitude needs to be interpreted with caution.

There was significant loss of knowledge after SCL's abbreviated high intensity training. At the estimated rate found in this study, knowledge would return to baseline in under 2 years for those who completed 6 month follow-up, while those who did not complete follow-up would return to baseline in less than 8 months. While Tuyisenge and colleagues demonstrated retention up to 9 months after training final year medical students in pediatric resuscitation,[18] our study is consistent with other studies in resuscitation training that demonstrate rapid loss of knowledge or skills, often in as little as in 6-12 weeks after training.[19-23] This has also been seen with clinical management of malaria[24] as well as with IMCI[10]. While the loss to follow-up in this study only allows us to estimate a range of the rate of knowledge loss, is notable that the most rapid estimate is not as rapid as other studies. Several reasons may account for this. It may be due to the contextualization process to ensure training was relevant to disease epidemiology and health system resources in Botswana. It may have been due to other components of SCL program besides aHIT. The SCL program integrates support in inventory of relevant medication and functioning equipment as part of its training and it provides immediate individual education on follow-up assessments by a master trainer. It is possible that similar results could have been obtained just from inventory support. The SCL program utilizes active reporting of training results to local health leadership – this may have stimulated additional feedback and support through administrative communication independent of the SCL program. Finally, it may be due to regression to the mean, as baseline knowledge scores were low and thus could only improve.

In this study, previous IMCI training did not significantly impact provider knowledge gained or retained from SCL-aHIT. That overall knowledge gained from SCL-aHIT was not negatively impacted supports the theory that programs such as SCL that focus on serious childhood illness may be an added value and not redundant to IMCI training. This may be especially important in environments where quality of pneumonia and diarrhea care is poor despite IMCI implementation. While IMCI-trained workers are more likely to correctly classify illnesses, administer oral therapies, employ rational antibiotic use, vaccinate children, and counsel families on adequate nutrition for moderate illness,[8,25] IMCI has limited impact on care delivery of the seriously ill child.[8-10] If there was significant overlap in content between SCL and IMCI, we might expect higher baseline scores and decreased acquisition. Alternatively, it may be that current existing IMCI training is not optimally effective.

Nurses, on average, scored significantly lower than physicians. This may be due to differences in pre-clinical education, in-service training, or unmeasured provider and environment characteristics that are highly correlated with professional status. Nevertheless, as nurses are the major training target for SCL-aHIT, further modifications to course content, structure or follow-up training may be needed.

Access to quality treatment of pneumonia and diarrhea are major contributors to avertable mortality worldwide.[4-6] Studies of provider performance show that standard guidelines were only followed 30-40% of the time, and often led to misallocation of resources.[26] Further, studies have shown that children with complex serious illness often receive worse care than those with milder, straightforward presentations.[27,28] This poor quality of services for treatable conditions is directly responsible for over 5 million deaths each year and contributes to decreased utilization of services, which accounts for another 3.6 million deaths.[6] A sustained and integrated improvement of provider knowledge and resource awareness is needed to address these gaps that currently limit systems to provide quality care.

Limitations:

As with any study there were several limitations. Use of an administrative database and infrastructure for the SCL program may have contributed to non-random loss to follow-up. Although effect was minimized through the conducted sensitivity analyses (see appendix), the study should be repeated with stronger support for follow-up data collection as well as training. Our outcome data was limited to knowledge assessments, and future studies that examine operational performance or patient outcomes are needed. The knowledge assessments have not been previously validated, and future studies should have multiple versions to better discriminate retention of test knowledge versus content knowledge. Finally, use of two time piece model assumes linearity throughout the follow-up period, and the true slope of knowledge retention may be non-linear.

Conclusion:

Abbreviated high intensity training focused on the seriously ill child significantly increases provider knowledge for both clinic and hospital-based providers. There appears to be significant loss of knowledge after initial training. IMCI training did not significantly impact overall knowledge acquisition or retention, but professional status impacted overall scores and loss to follow-up impacted retention of knowledge. In health systems where access to quality care for the seriously ill child is poor, programs such as Saving Children's Lives may have a significant impact if knowledge retention can be addressed.

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able 1: Provider Characteristics

T	Overall	IMCI trained	No IMCI	p value
N	211	95	116	
Professional Status*		[n (%)]	[n (%)]	
Nurse	187 (90.8)	91 (48.7)	96 (51.3)	0.0061
Physician	19 (9.2)	3 (15.8)	16 (84.2)	
Location of work***				
Clinic or Health post	127 (61.10)	62 (48.8)	65 (51.2)	0.2186
Hospital	52 (25.0)	23 (44.2)	29 (55.8)	
Other	29 (13.9)	9 (31.0)	20 (69.0)	
Mobile phone**				
Smart	111 (53.1)	57 (51.4)	54 (48.6)	0.0684
Text and Voice only or no cell phone	98 (46.9)	38 (38.8)	60 (61.2)	
English spoken most commonly				
Yes	51 (24.2)	15 (29.4)	36 (70.6)	0.0101
No	160 (75.8)	80 (50.0)	80 (50.0)	
Perceived frequency of resuscitation > 1 month****				
Yes	138 (66.7)	65 (47.1)	73 (52.9)	0.4896
No	69 (33.3)	29 (42.0)	40 (58.0)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia				
Agree	147 (69.7)	78 (53.1)	69 (46.9)	0.0004
Disagree/Neutral	64 (30.3)	17 (26.6)	47 (73.4)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Dehydration.				
Agree	168 (79.6)	80 (47.6)	88 (52.4)	0.1342
Disagree/Neutral	43 (20.4)	15 (34.9)	28 (65.1)	
Resuscitation Success (perceived)*				
0-25%	84 (40.8)	42 (50.0)	42 (50)	0.2832
26-50%	32 (15.5)	13 (40.6)	19 (59.4)	
51-75%	37 (18.0)	12 (32.4)	25 (67.6)	
76-100%	53 (25.7)	26 (49.1)	27 (50.9)	
Previous Resuscitation Training				
Pediatric****	23 (11.1)	12 (52.2)	11 (47.8)	0.4
Neonatal*	21 (10.2)	8 (38.1)	13 (61.9)	0.5538
Trauma*	21 (10.2)	7 (33.3)	14 (66.7)	0.2911
CPR***	73 (35.1)	29 (39.7)	44 (60.3)	0.3361
Year of the program***				
2014	162 (77.9)	77 (47.5)	85 (52.5)	0.3128
2015 or 2016	46 (22.1)	18 (39.1)	28 (60.9)	

Instructor Type***				
IFO	52 (25.0)	28 (53.9)	24 (46.1)	0.3872
LT70LF	96 (46.2)	44 (45.8)	52 (54.2)	
GT70LF	39 (18.8)	16 (41.0)	23 (59.0)	
LFO	21 (10.0)	7 (33.3)	14 (66.7)	

*5 participants did not report profession, resuscitation success (perceived), previous neonatal resuscitation or trauma training
** 2 did not report cellphone access
***3 did not report location of work, previous CPR training, year of training or instructor type
****4 did not report previous pediatric resuscitation training or perceived frequency of resuscitation
Previous Pediatric Resuscitation = Pediatric Advanced Life Support, Emergency Triage Assessment and Treatment
Previous Neonatal Resuscitation = Neonatal Resuscitation Training, Helping Babies Breathe.
Previous CPR: Cardiopulmonary Resuscitation
Other includes hospital based (administrative/'other')

Table 2: Characteristics of provider previous IMCI training

	N=95
Time since training	% (N)
< 6 months	14% (13)
>6months-2years	20% (19)
2-5yr	26% (25
>5 years	40% (38)
IMCI Course Duration	% (N)
< 7 days	74% (70)
≥ 7 days	26% (25)

Table 3: Models for Total Score Acquisition and Retention in Relation to Previous IMCI Training

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =655)	
	γ (SE)	***p***	**γ (SE)**	***p***	**γ (SE)**	***p***	**γ (SE)**	***p***
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**IMCI training added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	60.20 (0.90)	<.0001	43.08 (1.32)	<.0001	44.16 (1.78)	<.0001	45.70 (3.82)	<.0001
Previous IMCI training (yes vs. no)					-2.41 (2.65)	0.3641	-0.52 (2.45)	0.8336
Location of work (Clinic or Health post vs. Hospital)							-2.72 (1.96)	0.1677
Location of work (Other vs. Hospital)							-7.04 (2.77)	0.0125
Profession status (Physician vs. Nurse)							19.39 (3.30)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.91 (1.74)	0.6022
English spoken most commonly (Yes vs. No)							1.93 (2.28)	0.3989
Comfortable with treatment of severe pneumonia (Agree vs. Disagree/Neutral)							0.02 (1.77)	0.9903
Smartphone usage (Yes vs. No)							0.72 (1.57)	0.6453
Year of program (2014 vs. 2015 or 2016)							-4.04 (2.33)	0.0852
Had 6-month assessment (Yes vs. No)							1.91 (1.89)	0.313
Rate of Change (slope for timepiece one)								
Knowledge acquisition			26.37 (1.32)	<.0001	24.61 (1.88)	<.0001	24.56 (1.94)	<.0001
previous IMCI training (yes vs. no)					3.89 (2.79)	0.1655	3.58 (2.84)	0.2113
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-1.49 (0.46)	0.0014	-1.59 (0.66)	0.0172	-1.60 (0.67)	0.018
previous IMCI training (yes vs. no)					0.17 (0.92)	0.8574	0.20 (0.91)	0.824
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	399.07 (25.19)	<.0001	174.92 (18.14)	<.0001	174.79 (18.15)	<.0001	172.68 (17.89)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	41.59 (16.39)	0.0056	180.80 (39.60)	<.0001	181.40 (39.72)	<.0001	99.19 (34.29)	0.0019
Slope for knowledge acquisition			93.17 (48.81)	0.0281	91.31 (48.69)	0.0304	96.19 (48.85)	0.0245
Slope for knowledge retention			5.68 (3.36)	0.0452	5.95 (3.42)	0.041	5.43 (3.24)	0.0469
Goodness-of-Fit Statistics								
-2 Log Likelihood	6051.2		5736.6		5725.9		5428.3	
Akaike's Information Criterion	6055.2		5750.6		5739.9		5442.3	

Notes - Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO IMCI training. The intercept in Model 4 represents the baseline knowledge for the person who had no IMCI training, had SCL initial training in 2015/2016, were nurses, did not use smartphones, Setswana spoken most commonly, were discomfort with treatment of severe pneumonia, work in hospital, perception of frequency of resuscitation <=1 month, and did not complete a 6-month assessment.

Table 4 Models for Dehydration Sub-score Acquisition and Retention in Relation to Previous IMCI Training

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =655)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**IMCI training added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	26.37 (0.50)	<.0001	16.82 (0.77)	<.0001	16.77 (1.03)	<.0001	17.16 (2.24)	<.0001
Previous IMCI training (yes vs. no)					0.13 (1.54)	0.9304	1.06 (1.57)	0.5026
Location of work (Clinic or Health post vs. Hospital)							-2.24 (1.12)	0.048
Location of work (Other vs. Hospital)							-1.65 (1.59)	0.3023
Profession status (Physician vs. Nurse)							7.21 (1.89)	0.0002
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.76 (1.00)	0.4473
English spoken most commonly (Yes vs. No)							0.71 (1.31)	0.5901
Comfortable with treatment of severe pneumonia (Agree vs. Disagree/Neutral)							-0.97 (1.01)	0.3396
Smartphone usage (Yes vs. No)							0.27 (0.90)	0.7676
Year of program (2014 vs. 2015 or 2016)							-0.19 (1.34)	0.8905
Had 6-month assessment (Yes vs. No)							1.04 (1.08)	0.3361
Rate of Change (slope for timepiece one)								
Knowledge acquisition			14.74 (0.91)	<.0001	14.73 (1.23)	<.0001	14.58 (1.29)	<.0001
Previous IMCI training (yes vs. no)					0.04 (1.83)	0.9843	0.12 (1.90)	0.9511
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.92 (0.26)	0.0005	-1.16 (0.38)	0.0023	-1.10 (0.39)	0.0055
Previous IMCI training (yes vs. no)					0.46 (0.52)	0.3795	0.39 (0.54)	0.4681
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	137.48 (8.57)	<.0001	66.13 (6.78)	<.0001	66.02 (6.78)	<.0001	65.42 (6.75)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	9.55 (4.98)	0.0275	53.95 (13.70)	<.0001	54.64 (13.77)	<.0001	42.28 (13.51)	0.0002
Slope for knowledge acquisition			55.47 (20.16)	0.003	56.40 (20.26)	0.0304	63.18 (20.97)	0.0013
Slope for knowledge retention			1.23 (1.10)	0.1322	1.28 (1.11)	0.1256	1.34 (1.12)	0.1159
Goodness-of-Fit Statistics								
-2 Log Likelihood	5310.7		5032.1		5025.9		4798.2	
Akaike's Information Criterion	5314.7		5046.1		5039.9		4812.2	

Notes - Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO IMCI training. The intercept in Model 4 represents the baseline knowledge for the person who had no IMCI training, had SCL initial training in 2015/2016, were nurses, did not use smartphones, Setswana spoken most commonly, were discomfort with treatment of severe pneumonia, work in hospital, perception of frequency of resuscitation <=1 month, and did not complete a 6-month assessment.

Table 5 Models for Pneumonia Sub-score Acquisition and Retention in relation to Previous IMCI Training

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =655)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**IMCI training added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	33.84 (0.60)	<.0001	26.23 (1.00)	<.0001	27.36 (1.34)	<.0001	28.31 (2.77)	<.0001
Previous IMCI training (yes vs. no)					-2.52 (2.00)	0.2113	-1.74 (1.94)	0.3711
Location of work (Clinic or Health post vs. Hospital)							-0.78 (1.39)	0.575
Location of work (Other vs. Hospital)							-6.09 (1.96)	0.0024
Profession status (Physician vs. Nurse)							10.20 (2.30)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							-0.16 (1.23)	0.8943
English spoken most commonly (Yes vs. No)							2.26 (1.59)	0.1568
Comfortable with treatment of severe pneumonia (Agree vs. Disagree/Neutral)							0.72 (1.25)	0.5655
Smartphone usage (Yes vs. No)							0.49 (1.10)	0.6574
Year of program (2014 vs. 2015 or 2016)							-3.06 (1.66)	0.0676
Had 6-month assessment (Yes vs. No)							2.02 (1.31)	0.1287
Rate of Change (slope for timepiece one)								
Knowledge acquisition			11.56 (1.09)	<.0001	9.76 (1.47)	<.0001	9.83 (1.48)	<.0001
Previous IMCI training (yes vs. no)					3.96 (2.18)	0.0717	3.65 (2.17)	0.096
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.42 (0.28)	0.1422	-0.21 (0.41)	0.6084	-0.34 (0.42)	0.4229
Previous IMCI training (yes vs. no)					-0.45 (0.57)	0.4384	-0.39 (0.55)	0.4829
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	151.45 (9.83)	<.0001	79.17 (8.46)	<.0001	79.08 (8.46)	<.0001	78.49 (8.22)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	25.91 (7.80)	0.0004	124.93 (21.90)	<.0001	124.51 (21.90)	<.0001	94.07 (19.96)	<.0001
Slope for knowledge acquisition			106.84 (27.75)	<.0001	104.01 (27.56)	<.0001	95.09 (26.71)	0.0002
Slope for knowledge retention			2.09 (1.43)	0.0713	2.17 (1.45)	0.0671	2.06 (1.33)	0.0617
Goodness-of-Fit Statistics								
-2 Log Likelihood	5424.9		5266.9		5257.3		4986.7	
Akaike's Information Criterion	5428.9		5280.9		5271.3		5000.7	

Notes - Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO IMCI training. The intercept in Model 4 represents the baseline knowledge for the person who had no IMCI training, had SCL initial training in 2015/2016, were nurses, did not use smartphones, Setswana spoken most commonly, were discomfort with treatment of severe pneumonia, work in hospital, perception of frequency of resuscitation <=1 month, and did not complete a 6-month assessment.

Figure 1:

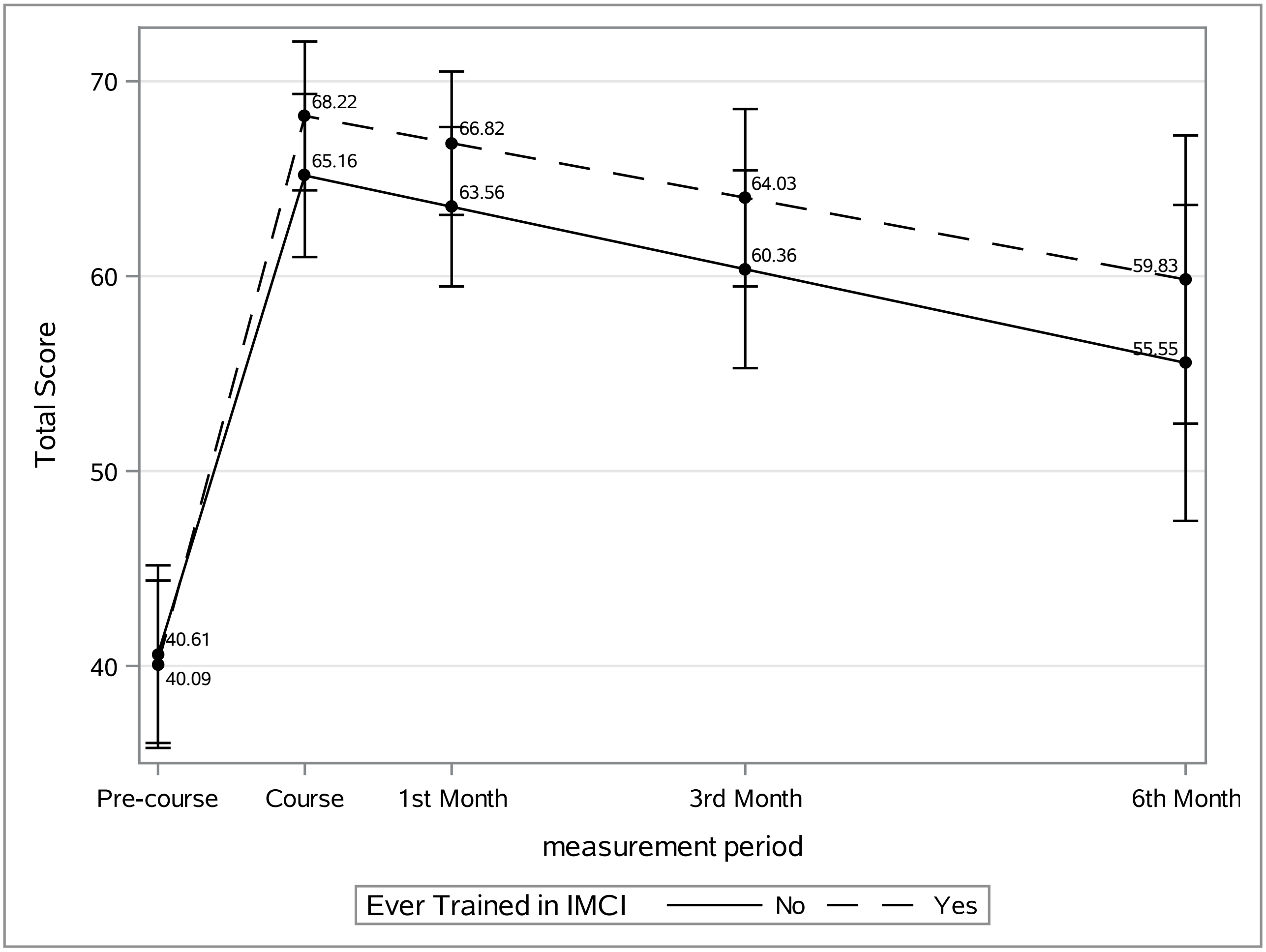
- Caption: Model-Based Marginal Total Score by IMCI Training over Time (adjusted)
- Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

Figure 2:

- Caption: Model-Based Dehydration Sub-Score by IMCI Training over Time (adjusted)
- Legend: Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment

Figure 3:

- Caption: Model-Based Pneumonia Sub-Score by IMCI Training over Time (adjusted)
- Legend: Legend: Plots were painted based on populations who had SCL initial training in 2014, were nurses, use smartphones, Setswana spoken most commonly, comfort with treatment of severe pneumonia, work in clinic/health post, perception of frequency of resuscitation >1 month, and did not complete a 6-month assessment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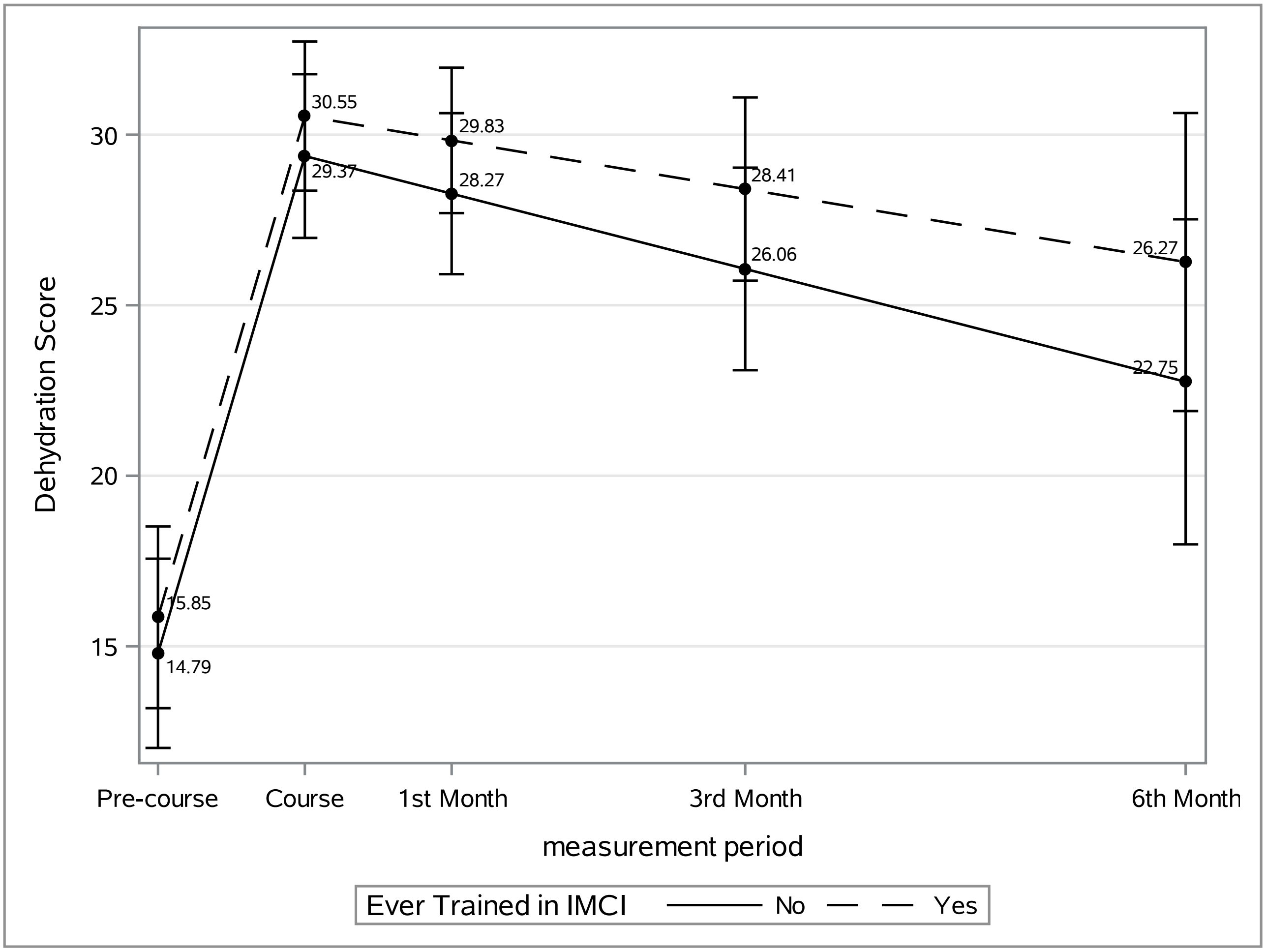
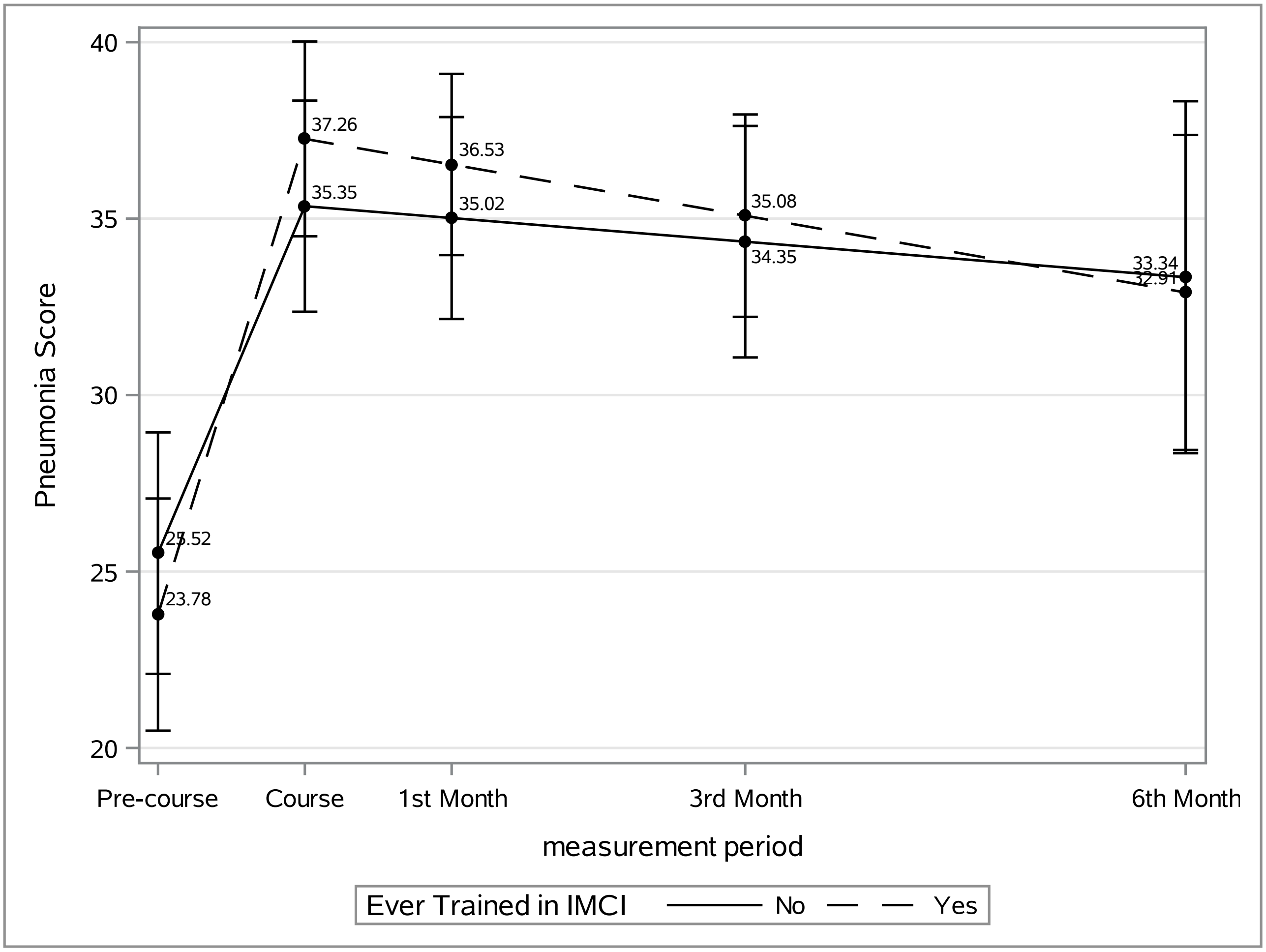
60
50
40
68.22
65.16
66.82
63.56
64.03
60.36
59.83
55.55
40.61
40.09
Pre-course
Course
1st Month
3rd Month
6th Month
measurement period
Ever Trained in IMCI
No
Yes

15:11 Friday, May 24, 2019 **2**




Pneumonia Score
40
35
30
25
20
37.26
35.35
36.53
35.02
35.08
34.35
33.34
32.91
25.52
23.78
Pre-course
Course
1st Month
3rd Month
6th Month
measurement period
Ever Trained in IMCI
No
Yes

Post-Hoc Testing/Sensitivity Analysis (Online Supplement):

Due to the significant loss of follow-up, we conducted a sensitivity analysis to examine if there was evidence of non-random missingness. To adjust for confounders, program year and work location was included in model as a priori. In addition, any student or course variable that was significantly different ($p<0.1$) between those completing 6-month follow-up and who did not, or had significantly different course assessment scores was included in the linear mixed model.

Variables considered potential confounders included in the sensitivity analysis included: year of initial training, degree of comfort with treatment of severe dehydration, ever previously trained in pediatric resuscitation, , ever previously trained in trauma resuscitation, ever previously trained in cardiopulmonary resuscitation, instructor mix, professional status, location of work, and perceived frequency of resuscitation > 1 month.

Overall, a strong and significant effect was seen with knowledge acquisition (b= +26.76, ±1.71, p <0.0001) (online supplement table B, Model 4), and there was significant loss of knowledge over time (b= -3.47 ±0.74 /month, p<.0001).

- Completing 6-month follow-up was not associated with baseline knowledge level (b=-2.81±3.29, p=0.3932), nor knowledge acquisition (b= +1.26 ±3.69, p= 0.7329), but a significant effect on knowledge retention (b= +3.03 ±0.88/month, p=0.0007).

- Dehydration sub scores had strong and significant effect was seen with knowledge acquisition (b= +14.68 ±1.10, p <0.0001), and strong and significant loss of knowledge over time (b= -1.56±0.45/month, p= 0.0006).

- Completing 6-month follow-up was not associated with baseline dehydration knowledge level (b=-1.69±2.10, p=0.4205), knowledge acquisition (b= +0.45±2.40, p=0.8529), nor knowledge retention (b= +0.84±0.54/month, p=0.118).

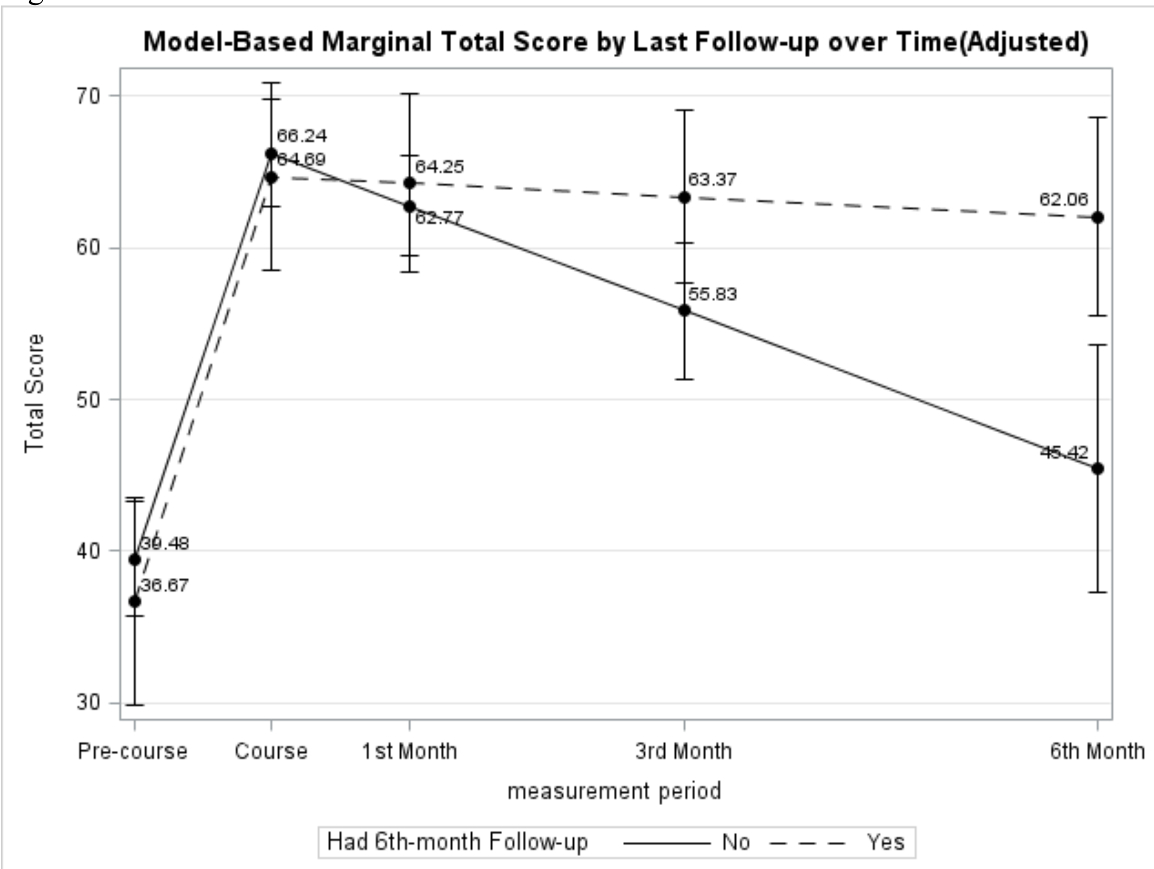
- Pneumonia sub scores had strong and significant effect was seen with knowledge acquisition (b= +12.07 ±1.27, p <0.0001), and significant loss of knowledge over time (b= -1.95 ±0.50/month, p<0.0001)
  - In the pneumonia sub score, completing 6-month follow-up was not associated with baseline knowledge level (b=-1.23±2.58), p=0.6345), nor knowledge acquisition (b= +0.81 ±2.76, p = 0.7683), but significant gain on retention (b= +2.24 ±0.6/month, p= 0.0003).

Table A: Provider Characteristics	Overall	Follow Up at 6 months	Lost to Follow up	p value
N	211	44	167	
Professional Status*		[n (%)]	[n (%)]	
Nurse	187 (90.8)	36 (19.3)	151 (80.7)	0.2038
Physician	19 (9.2)	6 (31.6)	13 (68.4)	
Location of work***				
Clinic or Health post	127 (61.1)	27 (21.3)	100 (78.7)	0.8260
Hospital	52 (25.0)	12 (23.1)	40 (76.9)	
Other	29 (13.9)	5 (17.2)	24 (82.8)	
Mobile phone**				
Smart	111 (53.1)	25 (22.5)	86 (77.5)	0.5791
Text and Voice only or no cell phone	98 (46.9)	19 (19.4)	79 (80.6)	
English spoken most commonly				
Yes	51 (24.2)	13 (25.5)	38 (74.5)	0.3492
No	160 (75.8)	31 (19.4)	129 (80.6)	
Perceived frequency of resuscitation > 1 month****				
Yes	138 (66.7)	27 (19.6)	111 (80.4)	0.4004
No	69 (33.3)	17 (24.6)	52 (75.4)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Pneumonia				
Agree	147 (69.7)	33 (22.4)	114 (77.6)	0.3872
Disagree/Neutral	64 (30.3)	11 (17.2)	53 (82.8)	
I am comfortable with the initial steps of stabilizing a pediatric patient with Severe Dehydration.				
Agree	168 (79.6)	39 (23.2)	129 (76.8)	0.0952
Disagree/Neutral	43 (20.4)	5 (11.6)	38 (88.4)	
Resuscitation Success (perceived)****				
0-25%	84 (40.8)	15 (17.8)	69 (82.1)	0.4269
26-50%	32 (15.5)	5 (15.6)	27 (84.4)	
51-75%	37 (18.0)	8 (21.6)	29 (78.4)	
76-100%	53 (25.7)	15 (28.3)	38 (71.7)	
Previous Resuscitation Training				
Pediatric ****	23 (11.1)	8 (34.8)	15 (65.2)	0.0877
Neonatal *	21 (10.2)	4 (19.0)	17 (81.0)	1
Trauma *	21 (10.2)	1 (4.8)	20 (95.2)	0.0846
CPR ***	73 (35.1)	21 (28.8)	52 (71.2)	0.0158
Year of the program***				
2014	162 (77.9)	39 (24.1)	123 (75.9)	0.023
2015 or 2016	46 (22.1)	4 (8.7)	42 (91.3)	
Instructor Type***				

IFO	52 (25.0)	33 (63.5)	19 (36.5)	<.0001
LT70LF	96 (46.2)	4 (4.2)	92 (95.8)	
GT70LF	39 (18.7)	5 (12.8)	34 (87.2)	
LFO	21 (10.10)	1 (4.7)	20 (95.2)	

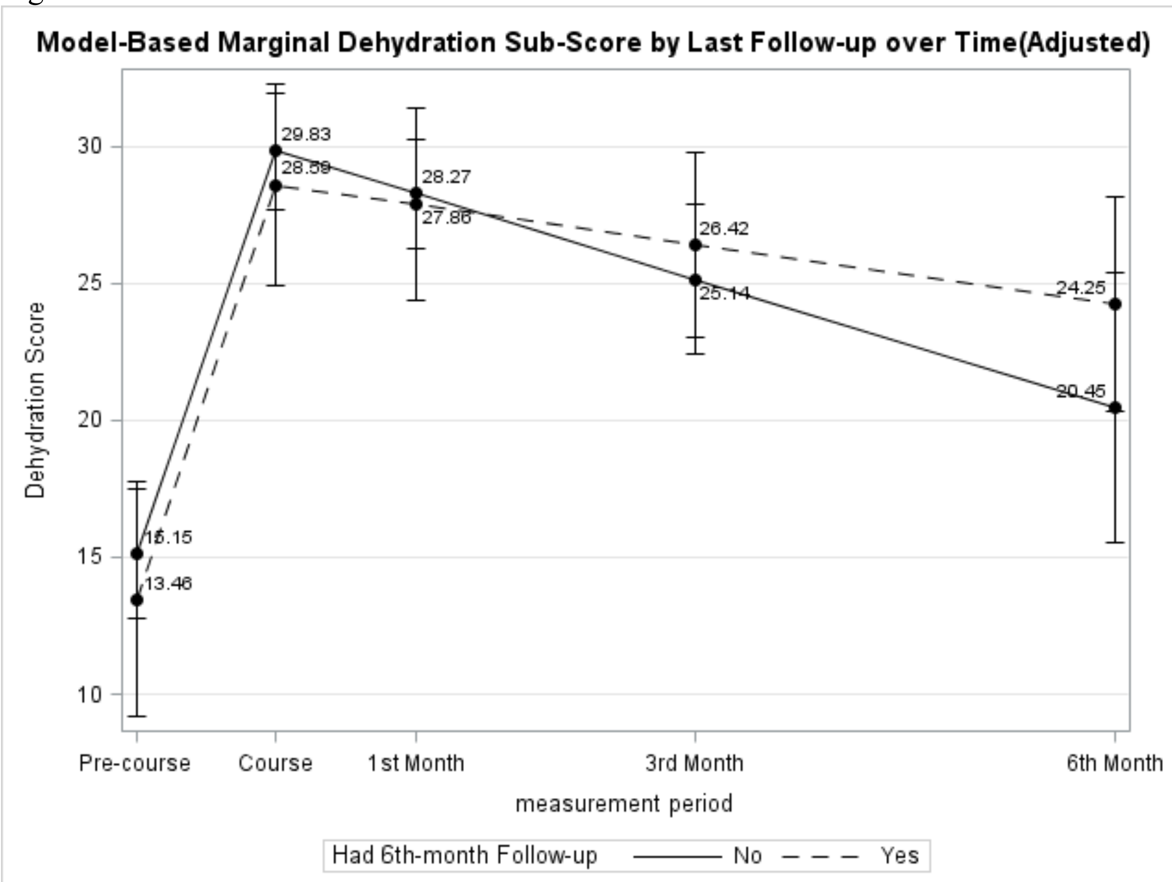
*5 participants did not report profession, previous neonatal or trauma resuscitation training.
** 2 did not report cellphone access
***3 did not report previous CPR training, location of work, year of training or instructor type
****4 did not report perceived frequency of resuscitation, resuscitation success (perceived), or previous pediatric resuscitation training.
Previous Pediatric Resuscitation = Pediatric Advanced Life Support, Emergency Triage Assessment and Treatment
Previous Neonatal Resuscitation = Neonatal Resuscitation Training, Helping Babies Breathe.
Previous CPR: Cardiopulmonary Resuscitation
Other includes hospital based (administrative/'other')

Figure A



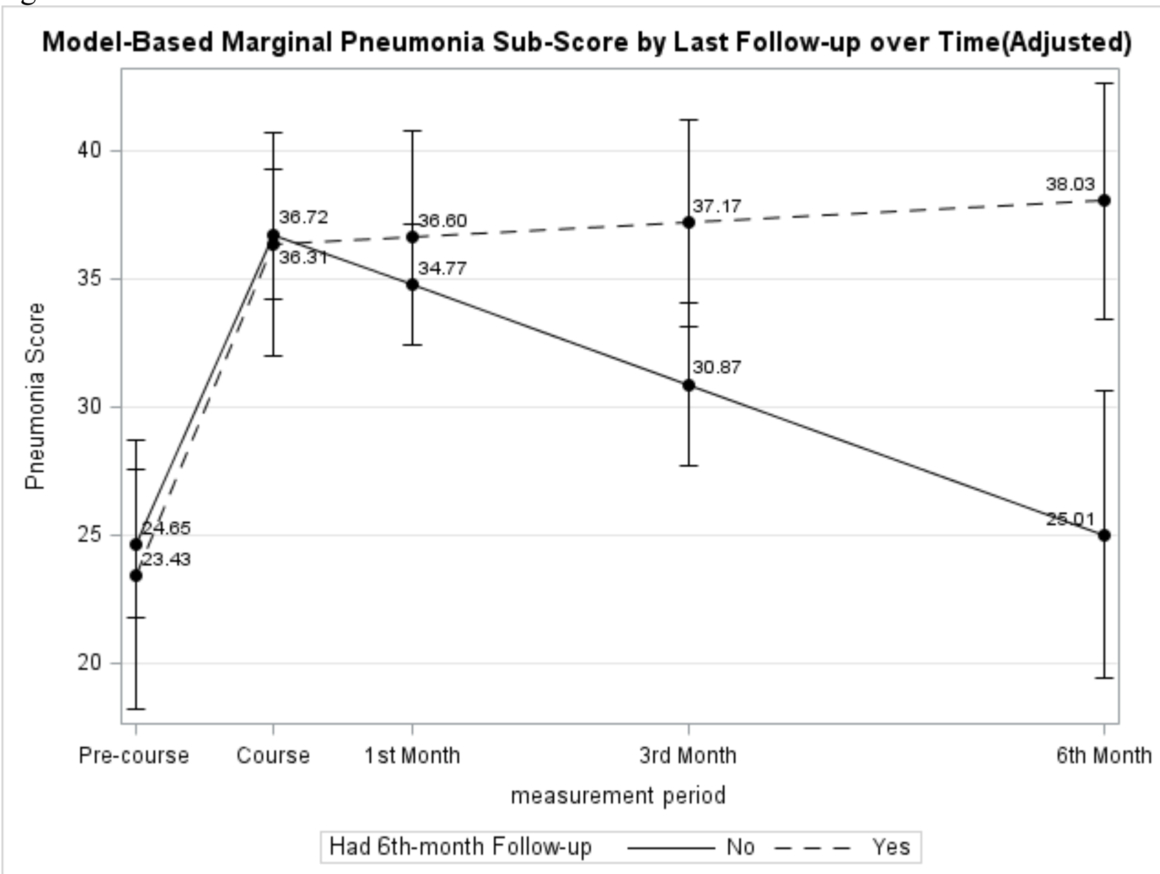
Plots were based on estimates of participants who received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, and perception of frequency of resuscitation >1 month.

Figure B



Plots were based on estimates of participants who received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, and perception of frequency of resuscitation >1 month.

Figure C



Plots were based on estimates of participants who received training in 2014, comfortable with a child severe dehydration, no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, course taught by less than 70% local instructors, nurses, work in clinic or health posts, and perception of frequency of resuscitation >1 month.

Table B Models for total score acquisition and retention by whether or not having 6-month assessment

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =635)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**6th-month follow-up added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	60.20 (0.90)	<.0001	43.04 (1.32)	<.0001	43.00 (1.49)	<.0001	41.84 (3.95)	<.0001
Had 6-month assessment (yes vs. no)					0.27 (3.22)	0.9331	-2.81 (3.29)	0.3932
Location of work (Clinic or Health post vs. Hospital)							-1.96 (2.04)	0.3382
Location of work (Other vs. Hospital)							-8.24 (2.78)	0.0034
Profession status (Physician vs. Nurse)							19.00 (2.74)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.36 (1.71)	0.8339
Year of program (2014 vs. 2015/ 2016)							-4.18 (2.68)	0.1209
Comfortable with treatment for severe dehydration (Agree vs. Disagree/Neutral)							3.42 (1.95)	0.0807
PALS/ETAT training ever (Yes vs. No)							-2.31 (2.82)	0.4137
Trauma training ever (Yes vs. No)							5.30 (2.76)	0.0555
CPR training ever (Yes vs. No)							2.48 (1.92)	0.1979
Instructor type (GT70LF vs. LT70LF)							2.06 (2.23)	0.3581
Instructor type (IFO vs. LT70LF)							4.49 (2.32)	0.054
Instructor type (LFO vs. LT70LF)							3.63 (3.73)	0.3322
Rate of Change (slope for timepiece one)								
Knowledge acquisition			26.12 (1.46)	<.0001	27.05 (3.22)	<.0001	26.76 (1.71)	<.0001
Had 6-month assessment (yes vs. no)					0.67 (3.49)	0.8472	1.26 (3.69)	0.7329
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.98 (0.37)	0.0091	-3.87 (0.73)	<.0001	-3.47 (0.74)	<.0001
Had 6-month assessment (yes vs. no)					3.57 (0.86)	<.0001	3.03 (0.88)	0.0007
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	399.07 (25.19)	<.0001	194.00 (16.03)	<.0001	187.54 (15.60)	<.0001	182.82 (15.69)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	41.59 (16.39)	0.0056	162.06 (38.74)	<.0001	170.06 (38.76)	<.0001	83.34 (32.81)	0.0055
Slope for knowledge acquisition			103.11 (43.88)	0.0094	108.67 (43.48)	0.0062	114.16 (44.51)	0.0052
Goodness-of-Fit Satistics								
-2 Log Likelihood	6051.2		5752.4		5720		5222.2	
Akaike's Information Criterion	6055.2		5760.4		5728		5230.2	

Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO 6-month assessment. The intercept in Model 4 represents the baseline knowledge for the person who had no 6-month assessment, had SCL initial training in 2015/2016, was nurses, discomfort with treatment of severe dehydration, worked in hospital, perception of frequency of resuscitation <=1 month, had no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, and course taught by less than 70% local instructors.

Table C Models for dehydration subscore acquisition and retention by whether or not having 6-month assessment

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =635)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**6th-month follow-up added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	26.37 (0.50)	<.0001	16.84 (0.77)	<.0001	16.75 (0.87)	<.0001	13.36 (2.37)	<.0001
Had 6-month assessment					0.43 (1.87)	0.8189	-1.69 (2.10)	0.4205
Location of work (Clinic or Health post vs. Hospital)							-1.24 (1.21)	0.3075
Location of work (Other vs. Hospital)							-1.23 (1.65)	0.4562
Profession status (Physician vs. Nurse)							5.98 (1.63)	0.0003
Perceived frequency of resuscitation >1 month (Yes vs. No)							0.73 (1.02)	0.4726
Year of program (2014 vs. 2015 or 2016)							0.52 (1.60)	0.7453
Comfortable with treatment of severe dehydration (Agree vs. Disagree/Neutral)							1.78 (1.16)	0.1251
PALS/ETAT training ever (Yes vs. No)							-0.93 (1.66)	0.5765
Trauma training ever (Yes vs. No)							1.12 (1.64)	0.496
CPR training ever (Yes vs. No)							2.34 (1.14)	0.0413
Instructor type (GT70LF vs. LT70LF)							0.24 (1.34)	0.8579
Instructor type (IFO vs. LT70LF)							3.56 (1.37)	0.0098
Instructor type (LFO vs. LT70LF)							3.27 (2.24)	0.1462
Rate of Change (slope for timepiece one)								
Knowledge acquisition			14.64 (0.92)	<.0001	14.78 (1.06)	<.0001	14.68 (1.10)	<.0001
Had 6-month assessment					0.93 (2.23)	0.6763	0.45 (2.40)	0.8519
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.76 (0.22)	0.0008	-1.68 (0.44)	0.0002	-1.56 (0.45)	0.0006
Had 6-month assessment					1.05 (0.52)	0.0448	0.84 (0.54)	0.118
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	137.48 (8.56)	<.0001	69.71 (5.77)	<.0001	69.34 (5.77)	<.0001	67.02 (5.79)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	9.55 (4.98)	0.0275	50.30 (13.21)	<.0001	51.24 (13.28)	<.0001	44.73 (13.22)	0.0004
Slope for knowledge acquisition			54.41 (17.51)	0.0009	55.99 (17.64)	0.0007	64.92 (18.70)	0.0003
Goodness-of-Fit Statistics								
-2 Log Likelihood	5310.7		5048.1		5033.8		4624.3	
Akaike's Information Criterion	5314.7		5056.1		5041.8		4632.3	

Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO 6-month assessment. The intercept in Model 4 represents the baseline knowledge for the person who had no 6-month assessment, had SCL initial training in 2015/2016, was nurses, discomfort with treatment of severe dehydration, worked in hospital, perception of frequency of resuscitation <=1 month, had no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, and course taught by less than 70% local instructors.

Table D Models for pneumonia subscore acquisition and retention by whether or not having 6-month assessment

	Model 1 (N = 679)		Model 2 (N = 679)		Model 3 (N = 679)		Model 4 (N =635)	
	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*	γ (SE)	*p*
Fixed Effects	**Unconditional Model**		**Unconditional Growth**		**6th-month follow-up added**		**Confounder-Adjusted**	
Initial Knowledge Status								
Intercept	33.84 (0.60)	<.0001	26.22 (1.00)	<.0001	26.27 (1.13)	<.0001	27.85 (2.89)	<.0001
Had 6-month assessment					-0.18 (2.44)	0.9416	-1.23 (2.58)	0.6345
Location of work (Clinic or Health post vs. Hospital)							-0.32 (1.48)	0.831
Location of work (Other vs. Hospital)							-6.87 (2.01)	0.0007
Profession status (Physician vs. Nurse)							11.71 (1.98)	<.0001
Perceived frequency of resuscitation >1 month (Yes vs. No)							-0.18 (1.24)	0.8874
Year of program (2014 vs. 2015 or 2016)							-4.33 (1.94)	0.0268
Comfortable with treatment of severe dehydration (Agree vs. Disagree/Neutral)							1.62 (1.41)	0.2502
PALS/ETAT training ever (Yes vs. No)							-1.31 (2.03)	0.5183
Trauma training ever (Yes vs. No)							3.78 (1.99)	0.0586
CPR training ever (Yes vs. No)							0.30 (1.39)	0.8272
Instructor type (GT70LF vs. LT70LF)							1.82 (1.63)	0.2661
Instructor type (IFO vs. LT70LF)							1.10 (1.67)	0.5108
Instructor type (LFO vs. LT70LF)							0.61 (2.72)	0.823
Rate of Change (slope for timepiece one)								
Knowledge acquisition			11.43 (1.09)	<.0001	12.24 (1.25)	<.0001	12.07 (1.27)	<.0001
Had 6-month assessment					-0.24 (2.62)	0.9282	0.81 (2.76)	0.7683
Rate of Change (slope for timepiece two)								
Knowledge retention per month			-0.23 (0.25)	0.3628	-2.24 (0.49)	<.0001	-1.95 (0.50)	<.0001
Had 6-month assessment					2.57 (0.58)	<.0001	2.24 (0.60)	0.0003
Variance Components								
Level 1	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*	σ^2 (SE)	*p*
Within-person	151.45 (9.83)	<.0001	88.40 (7.45)	<.0001	85.15 (7.22)	<.0001	84.62 (7.36)	<.0001
Level 2	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*	τ (SE)	*p*
Intercept	25.91 (7.80)	0.0004	115.75 (21.54)	<.0001	119.92 (21.59)	<.0001	84.93 (19.55)	<.0001
Slope for knowledge acquisition			93.09 (24.26)	<.0001	94.42 (23.92)	<.0001	93.07 (24.38)	<.0001
Goodness-of-Fit Statistics								
-2 Log Likelihood	5424.9		5270		5239.9		4806.4	
Akaike's Information Criterion	5428.9		5278		5247.9		4814.4	

Intercept for Model 1 is the grand mean in knowledge status across all time points; Intercept in Model 3 is the baseline knowledge for the group with NO 6-month assessment. The intercept in Model 4 represents the baseline knowledge for the person who had no 6-month assessment, had SCL initial training in 2015/2016, was nurses, discomfort with treatment of severe dehydration, worked in hospital, perception of frequency of resuscitation <=1 month, had no previous pediatric resuscitation training, no previous trauma training, no previous CPR training, and course taught by less than 70% local instructors.

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	3
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	3
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	#3	State specific objectives, including any prespecified hypotheses	6
Study design	#4	Present key elements of study design early in the paper	7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	6
	#6b	For matched studies, give matching criteria and number of exposed and	6

		unexposed	
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	7
Bias	#9	Describe any efforts to address potential sources of bias	6,9
Study size	#10	Explain how the study size was arrived at	6
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	6-9
	#12b	Describe any methods used to examine subgroups and interactions	6-9
	#12c	Explain how missing data were addressed	8
	#12d	If applicable, explain how loss to follow-up was addressed	9
	#12e	Describe any sensitivity analyses	9
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	10
	#13b	Give reasons for non-participation at each stage	9
	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	10
	#14b	Indicate number of participants with missing data for each variable of interest	12
	#14c	Summarise follow-up time (eg, average and total amount)	12

Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	10-12
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
	#16b	Report category boundaries when continuous variables were categorized	10-12
	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	10-12
Key results	#18	Summarise key results with reference to study objectives	13
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	16
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	16
Generalisability	#21	Discuss the generalisability (external validity) of the study results	16
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

 This checklist was completed on 05. February 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai