Measuring early child development in low and middle income countries: Investigating the validity of the early Human Capability Index

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ABSTRACT

Inclusion of early child development in the United Nations Sustainable Development Agenda raises issues of how this goal should be monitored, particularly in low resource settings. The aim of this paper was to explore the validity of the early Human Capability Index (eHCI); a population measure designed to capture the holistic development of children aged 3–5 years. Convergent, divergent, discriminant and concurrent validity were examined by exploring the associations between eHCI domains and child (sex, age, stunting status, preschool attendance) and family (maternal education, home learning environment) characteristics. Analyses were repeated using data from seven low and middle income countries: Brazil (n = 1810), China (n = 11421), Kiribati (n = 8339), Lao PDR (n = 7493), Samoa (n = 12191), Tonga (n = 6214), and Tuvalu (n = 549). Correlations and linear regressions provide evidence that within these country samples, the tool is capturing the aspects of early child development that it was designed to measure. Although the tool was intended to measure development of children aged 3–5 years, results suggest it can be validly applied to children aged 2–6 years. The eHCI is free, requires minimal implementation resources, captures development across domains and abilities, and is designed to allow cultural and contextual concepts to be included. The eHCI appears psychometrically robust in diverse country contexts and could enable evaluation of early years policies and programs, as well as monitoring of children's development to track progress towards the Sustainable Development Agenda.

1. Introduction

Monitoring children's outcomes is key to improving understanding of the early determinants of health and development because it helps identify the supports required to enable children to reach their developmental potential (Young, 2007). Tracking child health and development in low and middle income countries (LMICs) is a challenge due to lack of appropriate tools and capacity to implement measurement. The early Human Capability Index (eHCI) was designed to measure holistic development in children aged 3–5 years, be feasible for use in low resource settings, and capture locally-relevant early child development (ECD) (Sincovich et al., 2019). This paper explores the convergent, divergent, discriminant, and concurrent validity (Fig. 1) of the eHCI in several LMICs, highlighting how the tool could enable ECD

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measurement in these contexts.

1.1. The SDG challenge: characteristics of a useful measure of ECD in LMICs

Sustainable Development Goal (SDG) 4.2 is focused on ECD. To track progress against this target, countries are seeking population measures to better understand their children's early health and development. In addition to being psychometrically robust, such a measure needs to be cost-effective, therefore fees to use the tool, enumerator training required, and administration time need to be minimal (Fernald, Prado, Kariger, & Raikes, 2017). It should cover a range of development as well as levels of ability, and importantly, be sensitive enough to detect changes in children's capabilities (Mustard, 2007). Further, such a tool should be adaptable across diverse cultures and contexts so that it not only accurately reflects children's abilities, but also captures locally-relevant and culturally-influenced aspects of development to inform local policy and practice (Gove & Black, 2016).

The selection of a tool for the purposes of measuring ECD requires compromise among different priorities and measurement ideals determined by the aims of assessment, the age range of children, and any financial and logistical constraints. For instance, although the direct assessment of ECD (Pisani, Borisova, & Dowd, 2018) is often argued to produce scores with less bias than those through a measure of adult report (Bennetts, Mensah, Westrupp, Hackworth, & Reilly, 2016), this method of assessment requires highly trained enumerators, is more time consuming to conduct, more costly to implement and is infeasible for whole-of-population implementation (Snow & Van Hemel, 2008). Although adult report measures are generally more cost-effective as they are quick and simple to administer and do not rely on developmental expertise to be delivered (Ertem et al., 2017), often such tools are based on developmental milestones with a pass or fail outcome, lacking the sensitivity required to detect changes in development over time (Mustard, 2007). Although tools that produce globally comparable results (McCoy et al., 2016) allow for monitoring of ECD across countries, such instruments may not be aligned with local culture or early learning and development frameworks, and thus the information they produce may have limited utility locally (Keller & Kärtner, 2013). Local 'ownership' of results are crucial for local action to invest in ECD.

1.2. Measuring ECD at a population-level

Existing population-level measures of ECD include the Early Development Instrument (EDI) and UNICEF's Multiple Indicator Cluster Survey-Early Childhood Development Index (MICS-ECDI). The EDI was the first population-level measure of ECD to be implemented in multiple countries including Canada, the United States, Jamaica, and Australia (Janus, Harrison, Goldfeld, Guhn, & Brinkman, 2016). The 100-item checklist is completed by teachers of children in the first year of full-time school. The EDI formed the basis of the Australian Early Development Census (AEDC), a triennial national census of ECD which has captured over 1.2 million children across Australia to date (Brinkman, Gregory, Goldfeld, Lynch, & Hardy, 2014). The most widely utilized population-level measure of ECD is the MICS-ECDI. Consisting of

10 caregiver-reported items for children aged 3–4 years, the ECDI has been embedded in the MICS (i.e. a household survey) to collect globally comparable ECD information in more than 80 countries (UNICEF, 2017). Characteristics of both tools pose challenges to their use in diverse, low resource settings. For instance, the EDI licensing requirements and the specific intention of the ECDI for international comparison limit adaptation to local culture and context.

1.3. The eHCI

The eHCI was developed to facilitate program evaluation in Tonga by monitoring population-level child development (Brinkman & Thanh Vu, 2017; MacDonald et al., 2017). The tool has been adapted to support a range of early child education and development projects in several LMICs (Brinkman, Sincovich, & Danchev, 2016; Brinkman, Sincovich, & Than Vu, 2017; Brinkman, Sincovich, & Thanh Vu, 2017, 2017a; Santos & Zanon, 2017; Zhao et al., under review). Utilizing these data, the internal structure of the eHCI was explored, with results demonstrating a similar factor structure of nine theoretically-based developmental domains across countries (Sincovich et al., 2019). The current study examines the tool's convergent, divergent, discriminant, and concurrent validity using data from seven LMICs: Brazil, China, Kiribati, Lao People's Democratic Republic (PDR), Samoa, Tonga, and Tuvalu. We examine associations between eHCI domain scores for evidence of convergent and divergent validity; the ability of eHCI domain scores to discriminate among children of different age, sex, stunting status, preschool attendance, maternal education, and home learning environments (discriminant validity); and associations between scores on eHCI domains and direct assessment of literacy and numeracy for evidence of concurrent validity.

2. Method

2.1. Participants

Data from seven country samples were utilized (Table 1). Sample sizes ranged from 549 in Tuvalu to 12,191 in Samoa, with children aged between 2 and 6 years. Data were collected from 2013 to 17 through studies funded for program evaluation and population monitoring purposes by local, national, and international agencies that utilized different sampling techniques and data collection methods (Supplementary Table 1). In Brazil, data were collected from teachers for children attending all 37 public schools in a city in Southern Brazil, to identify areas of intervention and enable evaluation of ECD programs (Santos & Zanon, 2017). In China, data were collected for children in two Northern provinces selected by the China Development Research Foundation on the basis of pre-existing programs in these areas (Zhao et al., under review). Respondents were a combination of children's caregivers and teachers, with data collected to explore development across different population groups, as well as to form a baseline of ECD before further intervention. In Lao PDR, data were collected from children's caregivers to form the baseline for a randomized control trial. Five Northern provinces were selected by the Government of Lao PDR based on high levels of poverty, and 14 districts within these provinces

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Convergent validity is evident when measures of theoretically related constructs are highly correlated.

Divergent validity is evident when measures of theoretically less related constructs are not highly correlated.

Discriminant validity is evident when measures produce scores that differ according to participant characteristics, such as sex and age, as theoretically expected.

Concurrent validity is evident when measures of constructs are highly correlated with previously established measures of the same construct.

Fig. 1. Types of validity explored in current study.

Table 1
Sample characteristics for data collected in 7 LMICs from 2013 to 2017.

	Brazil n (%)	China n (%)	Kiribati n (%)	Lao PDR n (%)	Samoa n (%)	Tonga n (%)	Tuvalu n (%)
Sex							
Female	855 (47.2)	5338 (46.7)	3915 (46.9)	3669 (49.0)	5898 (48.4)	2967 (47.7)	277 (50.5)
Missing	102 (5.6)	496 (4.3)	155 (1.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Age							
2 years	57 (3.1)	54 (0.5)	948 (11.4)	1410 (18.8)	1159 (9.5)	13 (0.2)	1 (0.2)
3 years	571 (31.5)	3396 (29.7)	2185 (26.2)	1749 (23.3)	4377 (35.9)	1609 (25.9)	163 (29.7)
4 years	760 (42.0)	3329 (29.1)	2136 (25.6)	1867 (24.9)	4616 (37.9)	2058 (33.1)	180 (32.8)
5 years	420 (23.2)	3360 (29.4)	2013 (24.1)	1599 (21.3)	2039 (16.7)	2038 (32.8)	195 (35.5)
6 years	0 (0.0)	1226 (10.7)	173 (2.1)	16 (0.2)	0 (0.0)	443 (7.1)	7 (1.3)
Missing	2 (0.1)	56 (0.5)	884 (10.6)	852 (11.4)	0 (0.0)	53 (0.9)	3 (0.5)
Stunted							
Yes	–	1602 (14.0)	1935 (23.2)	3652 (48.7)	2332 (19.1)	374 (6.0)	132 (24.0)
Missing	–	1342 (11.8)	1401 (16.8)	852 (11.4)	0 (0.0)	91 (1.5)	98 (17.9)
Preschool							
Attended	1810 (100.0)	9159 (80.2)	7665 (91.9)	1738 (23.2)	4657 (38.2)	2701 (43.5)	498 (90.7)
Missing	0 (0.0)	86 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Maternal Education							
No school	–	307 (2.7)	–	2265 (30.2)	–	–	–
Started Primary	–	1242 (10.9)	714 (8.6)	2045 (27.3)	–	–	–
Finished Primary	–	3372 (29.5)	1438 (17.2)	2182 (29.1)	222 (1.8)	81 (1.3)	47 (8.6)
Started Secondary	–	3563 (31.2)	2319 (27.8)	–	603 (4.9)	2399 (38.6)	89 (16.2)
Finished Secondary	–	1358 (11.9)	2710 (32.5)	754 (10.1)	10037 (82.3)	2621 (42.2)	107 (19.5)
Tertiary	–	751 (6.6)	785 (9.4)	242 (3.2)	1329 (10.9)	1107 (17.8)	117 (21.3)
Missing	–	828 (7.2)	373 (4.5)	5 (0.1)	0 (0.0)	0 (0.0)	189 (34.4)
Home learning environment							
Read to	–	–	3930 (47.1)	2149 (28.7)	2424 (19.9)	3566 (57.4)	297 (54.1)
Missing	–	–	6 (0.1)	0 (0.0)	3470 (28.5)	704 (11.3)	164 (29.9)
Tell story	–	–	5886 (70.6)	1903 (25.4)	2856 (23.4)	3836 (61.7)	337 (61.4)
Missing	–	–	6 (0.1)	0 (0.0)	3470 (28.5)	702 (11.3)	165 (30.1)
Sing/dance	–	–	4964 (59.5)	2215 (29.6)	5043 (41.4)	5025 (80.9)	353 (64.3)
Missing	–	–	6 (0.1)	0 (0.0)	3470 (28.5)	700 (11.3)	165 (30.1)
Play	–	–	4774 (57.2)	1341 (17.9)	4800 (39.4)	5180 (83.4)	359 (65.4)
Missing	–	–	6 (0.1)	0 (0.0)	3470 (28.5)	699 (11.2)	165 (30.1)
Go outside	–	–	3455 (41.4)	1775 (23.7)	4722 (38.7)	5174 (83.3)	338 (61.6)
Missing	–	–	6 (0.1)	0 (0.0)	3470 (28.5)	700 (11.3)	165 (30.1)
Name, count, draw	–	–	3380 (40.5)	2280 (30.4)	2720 (22.3)	3152 (50.7)	309 (56.3)
Missing	–	–	6 (0.1)	0 (0.0)	3470 (28.5)	701 (11.3)	166 (30.2)
Books in home	–	–	3948 (47.3)	–	6253 (51.3)	4129 (66.4)	–
Missing	–	–	267 (3.2)	–	0 (0.0)	11 (0.2)	–
Total n	1810	11421	8339	7493	12191	6214	549

Note. Children's height and weight, maternal education, and home learning environment data were not collected in Brazil. Home learning environment data were not collected in China. Information regarding books in the home was not collected in Laos PDR and Tuvalu. In Samoa, Tonga, and Tuvalu, when responding to the maternal education item, respondents could select only one response option pertaining to primary school and so the proportions represented against the 'finished primary school' category for these countries may include a combination of children for whom their mother either started or finished primary school.

were selected on the basis of presence of a district level education office. All villages within selected districts in which at least 20 children resided were sampled, and random sampling methods were used to select 20 households in each village for data collection (Brinkman, Sincovich, & Danchev, 2016). In Kiribati, Samoa, Tonga, and Tuvalu, a census approach was employed with data collection seeking to capture information from a combination of caregivers and teachers for every child aged 3–5 years nationally (Brinkman, Sincovich, & Danchev, 2016; Brinkman, Sincovich, & Than Vu, 2017; Brinkman, Sincovich, & Than Vu, 2017; 2017a).

2.2. Measures

2.2.1. The eHCI

The eHCI is unlicensed and free to use, requires minimal enumerator training, and can be completed quickly by an adult familiar with the child. Thus, the eHCI can be implemented feasibly across large populations in low resource settings. The tool captures both positive and negative aspects of how a child is developing, rather than developmental delay only. The eHCI places children on a developmental continuum which improves ability to detect changes in development over time and/ or through intervention. Further, the eHCI was designed to be adapted to local culture and context for a range of purposes, including population monitoring, evaluation of early years policies and programs, and longitudinal studies seeking to predict children's future capabilities.

The eHCI includes approximately 60 items (ranging from 56 in Lao PDR to 66 in Tuvalu) designed to measure ECD across nine domains: Physical Health, Verbal Communication, Cultural Knowledge, Social and Emotional Skills, Perseverance, Approaches to Learning, Numeracy, Reading, and Writing. The eHCI underwent a local adaptation process to ensure the tool's content and face validity in each country. Thus, although many items are similar across different adaptations of the eHCI, some items and domains differ across countries. For instance, the Perseverance domain is measured by the same four items across all adaptations of the instrument, while the Physical Health domain varies from 2 items in Brazil to 5 items in Kiribati and Tuvalu, while the Laotian version of the eHCI does not capture physical health (each country adaptation is available in Sincovich et al., 2019). In each country, all items are applied to all children (i.e. rather than a sub-group of items for different age groups). Response options for each item are binary ("yes"/"no", "able"/"unable", "can do already"/"cannot do yet"). Most items are positively worded so that the "yes"/"able"/"can do already" responses were scored as 1, and the "no"/"unable"/"cannot do yet" responses were scored as 0. A small number of items (ranging from 4 in Kiribati and Lao PDR to 6 in Tonga) are negatively worded and were reverse-scored. Individual item scores were averaged so that children

received a score for each domain ranging from 0 to 1, with higher scores indicative of better development.

2.2.2. Demographic characteristics

Children's demographic characteristics were collected alongside the eHCI in each country, including child age, sex, previous or current preschool attendance, and their mother's highest level of education (except in Brazil).

2.2.3. Stunting

Children's height and weight were also recorded at the time of data collection in each country (except in Brazil). Anthropometric measures were converted into World Health Organization Child Growth Standards height-for-age z-scores, and stunting was defined as a height-for-age z-score < -2 (WHO Multicentre Growth Reference Study Group, 2006).

2.2.4. Home learning environment

Information about caregiver-child engagement in six types of learning activities at home was also collected alongside the eHCI in each country (except in China and Brazil). These binary questions ("yes"/"no") were based on items from the Multiple Indicator Cluster Surveys (MICS) questionnaire for children under five (UNICEF, 2019) and asked if, in the last 3 days (or in the last 7 days in Lao PDR and Tonga), a member of the household aged 15 years or above had: read books or looked at picture books with the child; told stories to the child; sang songs or danced with the child; played with the child; took the child outside of the home; and named, counted or drew with the child. In Kiribati, Samoa, and Tonga, respondents were also asked if there were reading materials in the home (also based on the MICS with a "yes"/"no" response option).

2.2.5. Literacy and numeracy

Concurrent to administration of the eHCI in Lao PDR, children's literacy and numeracy were measured via direct assessment. These assessments were based on items from the Early Grade Reading Assessment (EGRA) and the Early Grade Maths Assessment (EGMA), and adapted to the context in Lao PDR (Brinkman, Sincovich, & Danchev, 2016). The EGRA and EGMA have been adapted for use in a number of countries, with the reliability and validity of the EGRA in particular, well established (Dubeck, Gove, & Alexander, 2016). In Lao PDR, children were assessed on six aspects of early literacy and eight aspects of early numeracy (Supplementary Table 2). Correct item responses were scored as 1, and incorrect responses were scored as 0. For domains measured via multiple items, individual item scores were averaged so that children received a score for each domain, ranging from 0 to 1, with higher scores indicative of better literacy and numeracy. All literacy domain scores were averaged to provide a total literacy score, and all numeracy domain scores were averaged to provide a total numeracy score.

2.3. Statistical analysis

Convergent and divergent validity were tested by examining patterns of correlation (Spearman's rho) amongst eHCI domains in each country. We predicted that the strongest associations would be observed between eHCI domains measuring children's literacy and numeracy, with smaller correlations between remaining domains. The ability of eHCI domains to discriminate amongst children's development by a range of child and family characteristics was tested in each country. Discriminant ability according to child age (2–6 years), child sex (female, male), child stunting status (yes, no), child preschool attendance (yes, no), maternal education (no school, started primary school, finished primary school, started secondary school, finished secondary school, tertiary education), and home learning environment items (yes, no) were examined using linear regressions. Children with missing data were excluded from relevant analyses. Density plots for eHCI domains were generated to further explore the distribution of domain scores by child and family characteristics in each country, and unstandardized regression coefficients were graphed to examine associations amongst eHCI domains and child and family characteristics in each country. We expected that higher domain scores would be observed among females, older children, those not stunted, children who attended preschool, children of more educated mothers, and children with learning opportunities at home. Concurrent validity was tested by exploring correlations (Spearman's rho) among eHCI domains and literacy and numeracy direct assessment in Lao PDR. We hypothesized that the strongest associations would be observed between direct assessment scores and eHCI domains measuring literacy and numeracy, with smaller correlations between direct assessment scores and remaining eHCI domains.

3. Results

Correlations amongst eHCI domains are shown in Table 2. The largest correlations were observed amongst Numeracy, Reading, and Writing domains in all countries (ranging from $r_s = 0.54$ in Lao PDR to $r_s = 0.85$ in Tuvalu between Numeracy and Reading). Smaller correlations were observed between Physical Health and other domains in Brazil and China ($r_s = 0.16$ with Writing in China), and between Perseverance and other domains in Kiribati, Lao PDR, Samoa, and Tonga ($r_s = 0.08$ with Approaches to Learning in Samoa).

Mean eHCI domain scores according to child and family characteristics are presented in Supplementary Tables 3–8. Regression coefficients demonstrating associations among eHCI domain scores and these characteristics are shown in Supplementary Table 9, with Figs. 2–3 providing examples for Tonga and Lao PDR. Data for remaining countries are shown in Supplementary Figs. 1–5. Results show a positive association between child age and eHCI domain scores in all countries. Generally, the largest differences between older and younger children were found on Numeracy, Reading, and Writing domains, with smaller differences on remaining domains (e.g. a year increase in age was associated with a score 0.23 (95% CI: 0.22, 0.24) points higher on the Writing domain and 0.04 (95% CI: 0.03, 0.04) points higher on Social and Emotional Skills in Tonga). Fig. 4 shows a visual representation of these age gradients for Numeracy and Social and Emotional Skills domains in each country. On average, girls scored slightly higher than boys across domains, except in Brazil. This association was strongest in Tuvalu (e.g. female sex was associated with a score 0.10 (95% CI: 0.06, 0.14) points higher on Social and Emotional Skills and 0.11 (95% CI 0.05, 0.17) points higher on Reading). A negative association between child stunting and eHCI domain scores was observed, with stunted children scoring lower across domains in all countries, compared to children not stunted. Differences in scores tended to be larger on Numeracy, Reading, and Writing domains, and smaller on Social and Emotional Skills and Perseverance domains (e.g. being stunted was associated with a score 0.14 (95% CI: -0.22, -0.07) points lower on the Writing domain and 0.02 (95% CI: -0.07, 0.03) points lower on Social and Emotional Skills in Tuvalu), though this association was less clear in Tonga whereby prevalence of stunting was low. Children who attended preschool had better development than those who did not, with the largest differences in scores on Numeracy, Reading, and Writing domains (e.g. preschool attendance was associated with a score 0.44 (95% CI: 0.43, 0.45) points higher on the Numeracy domain and 0.17 (95% CI: 0.16, 0.19) points higher on Approaches to Learning in China). Fig. 5 demonstrates these differences in eHCI scores for children who did and did not attend preschool on the Numeracy and Social and Emotional Skills domains in each country.

Results also demonstrate a positive association between maternal education and eHCI domain scores, with children of more educated mothers scoring slightly higher across eHCI domains relative to children of less educated mothers in all countries but Tuvalu (e.g. a category increase in maternal education was associated with a score 0.09 (95% CI: 0.07, 0.10) points higher on the Reading domain in Samoa). A

Table 2
Convergent and divergent validity: correlations among scores on eHCI domains in 7 LMICs.

	Phys	Comm	Cult	Soc	Persev	Appr	Num	Read
Brazil								
Comm	.13							
Cult	.10	.37						
Soc	.08	.26	.19					
Persev	.14	.38	.32	.43				
Appr	.12	.43	.30	.29	.29			
Num	.16	.47	.50	.41	.34	.34		
Read	.15	.37	.38	.31	.24	.67	.67	
Writ	.15	.32	.43	.15	.29	.22	.63	.66
China								
Comm	.20							
Cult	.32	.48						
Soc	.32	.43	.70					
Persev	.12	.28	.34	.45				
Appr	.23	.54	.57	.54	.34			
Num	.27	.40	.47	.45	.25	.47		
Read	.42	.39	.47	.45	.32	.44	.67	
Writ	.16	.29	.32	.32	.26	.31	.62	.66
Kiribati								
Comm	.40							
Cult	.46	.61						
Soc	.42	.53	.71					
Persev	.21	.21	.27	.30				
Appr	.31	.39	.48	.48	.21			
Num	.43	.53	.61	.52	.24	.46		
Read	.39	.47	.54	.45	.22	.41	.76	
Writ	.37	.43	.51	.42	.20	.36	.72	.70
Lao PDR								
Comm	–							
Cult	–	.31						
Soc	–	.31	.46					
Persev	–	.09	.24	.27				
Appr	–	.43	.36	.45	.14			
Num	–	.30	.42	.50	.25	.37		
Read	–	.16	.38	.41	.20	.27	.52	
Writ	–	.12	.35	.42	.21	.28	.50	.55
Samoa								
Comm	.56							
Cult	.57	.61						
Soc	.57	.64	.81					
Persev	.16	.10	.25	.22				
Appr	.45	.63	.53	.61	.08			
Num	.48	.51	.69	.70	.26	.47		
Read	.46	.54	.68	.71	.20	.51	.78	
Writ	.46	.46	.63	.64	.25	.43	.75	.77
Tonga								
Comm	.34							
Cult	.48	.51						
Soc	.46	.38	.48					
Persev	.22	.21	.21	.24				
Appr	.34	.38	.46	.36	.20			
Num	.46	.37	.49	.40	.25	.43		
Read	.39	.33	.42	.36	.25	.38	.76	
Writ	.38	.26	.40	.32	.21	.34	.76	.73
Tuvalu								
Comm	.44							
Cult	.55	.67						
Soc	.48	.51	.67					
Persev	.36	.39	.45	.56				
Appr	.29	.36	.44	.41	.32			
Num	.52	.67	.69	.54	.44	.40		
Read	.56	.66	.69	.55	.42	.43	.85	
Writ	.47	.54	.57	.44	.42	.44	.74	.76

Note. p < .001 for all correlations (Spearman's rho). The Lao PDR version of the eHCI does not include a Physical Health domain. Phys = Physical Health, Comm = Verbal Communication, Cult = Cultural Knowledge, Soc = Social and Emotional, Persev = Perseverance, Appr = Approaches to Learning, Num = Numeracy, Read = Reading, and Writ = Writing.

positive association was also observed between home learning activities and eHCI domain scores in each country. Of all home environment items, the largest differences in scores were observed between children who did and did not have access to books at home on Numeracy, Reading and Writing domains (e.g. having books in the home was associated with a score 0.21 (95% CI: 0.19, 0.22) points higher on the Writing domain and 0.12 (95% CI: 0.11, 0.13) points higher on Physical Health in Kiribati). Differences in scores between children who were and were not read to, told stories, and named, counted and drew with were also larger across domains, while differences in scores were smaller for remaining activities (e.g. naming, counting, or drawing was associated with a score 0.18 (95% CI: 0.16, 0.19) points higher on the Numeracy domain, while taking the child outside was associated with a score 0.16 (95% CI: 0.05, 0.08) points higher on Numeracy in Lao PDR).

Correlations between eHCI domains and literacy and numeracy direct assessment in Lao PDR are shown in Table 3. Both direct assessment scores had the largest positive correlations with eHCI Numeracy, Reading, and Writing ($r_s = 0.50$ between direct assessment and eHCI numeracy domains), and smaller correlations with remaining domains ($r_s = 0.18$ between literacy direct assessment and eHCI Perseverance).

4. Discussion

We examined the convergent, divergent, and discriminant, validity of the eHCI in Brazil, China, Kiribati, Lao PDR, Samoa, Tuvalu, and Tonga, and the concurrent validity of the tool in Lao PDR. Despite different sampling methods and items used across countries, the overall pattern of results suggests the eHCI provides valid measurement of ECD in these contexts.

4.1. Evidence for validity of the eHCI

The strongest associations were observed amongst eHCI Numeracy, Reading, and Writing domains in all countries. Literacy and numeracy are often intertwined; indeed some ECD tools combine items measuring these skills into one domain because of their strong relationship (Janus et al., 2016). Overall results provided evidence for the convergent and divergent validity of the eHCI.

eHCI domain scores discriminated between children's development according to age and sex in all countries. This is consistent with results of other measures of ECD in LMICs, including the East Asia Pacific Early Child Development Scales (EAP-ECDS), a direct assessment of development in children aged 3–5 years, across Cambodia, China, Mongolia, Timor-Leste, Papua New Guinea, and Vanuatu (Rao, Sun, et al., 2018). Although the eHCI was designed to measure ECD in children aged 3–5 years, results suggest it can be validly applied to children aged 2–6 years. Stunting impairs children's development with effects particularly detrimental to cognitive abilities (Alderman & Fernald, 2017). In all countries eHCI scores were lower among stunted children, with the largest differences in scores on cognitive domains capturing literacy and numeracy. This is also aligned with results of other tools, such as the Caregiver Reported Early Development Instrument (CREDI) for children aged 0–2 years across 17 low, middle, and high middle income countries (McCoy, Waldman, Team, & Fink, 2018). A positive association between early education and ECD was also observed, with differences in scores between children who did and did not attend preschool largest on Numeracy, Reading, and Writing. In contrast, results from a direct assessment, Measure of Development and Early Learning (MODEL), of children aged 4–8 years in Tanzania did not find a relationship between pre-primary education and children's development as was expected (Raikes et al., 2019), whereas cognitive, language and socio-emotional development as measured by the EAP-ECDS was higher amongst children aged 3–5 years who had attended early education in Cambodia, China, Mongolia, and Vanuatu (Rao et al., 2018). Higher eHCI scores were generally observed among children born to better educated mothers, except in Tuvalu. This sample represents poor families from a
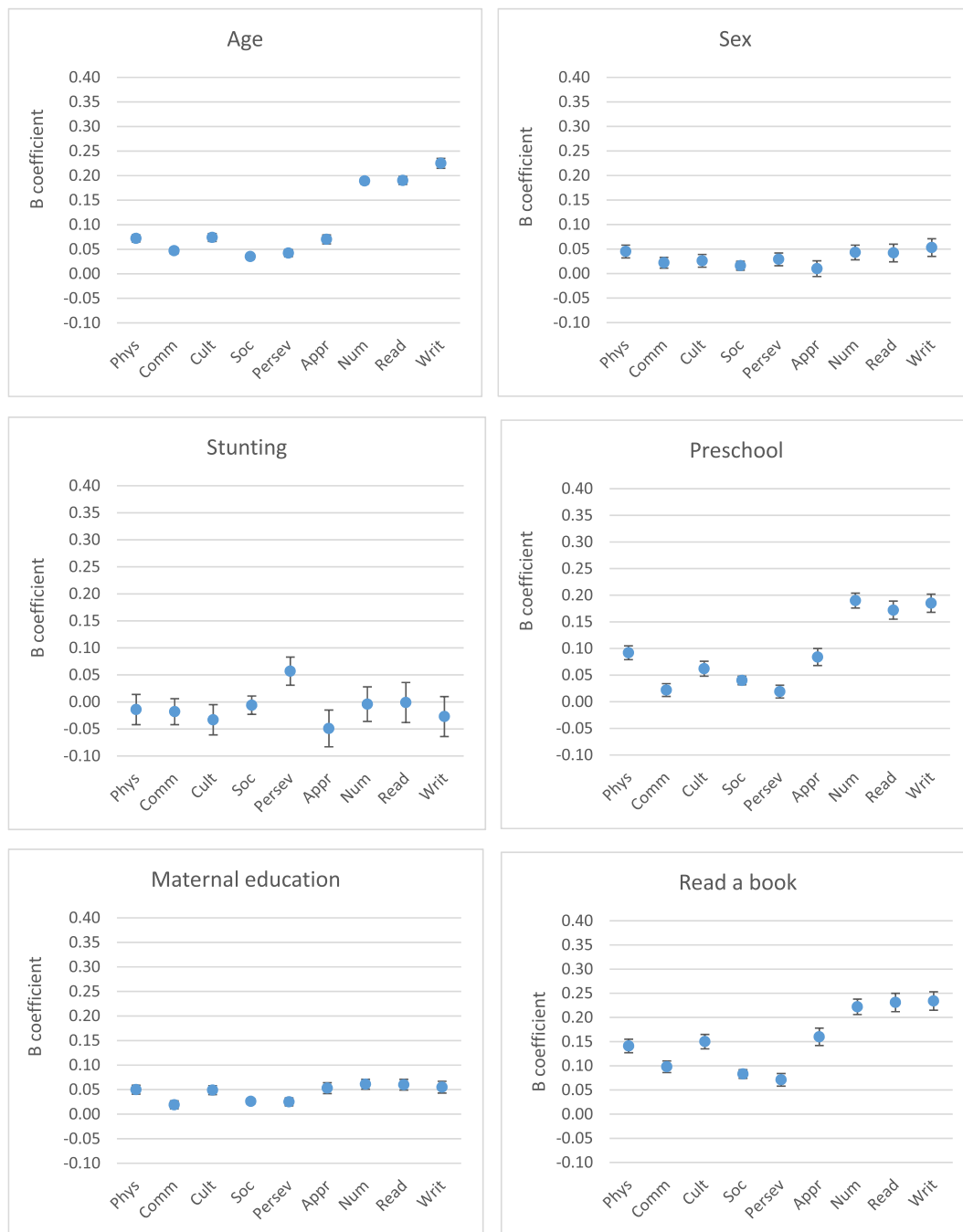
Fig. 2. Discriminant validity: linear regression coefficients and 95% confidence intervals of eHCI domain scores on demographic and contextual variables in Tonga (n = 6214, 2013/14).

Note. Female, stunted, attended preschool, home learning environment yes = 1; male, not stunted, did not attend preschool, home learning environment items no = 0. Phys = Physical Health, Comm = Verbal Communication, Cult = Cultural Knowledge, Soc = Social and Emotional, Persev = Perseverance, Appr = Approaches to Learning, Num = Numeracy, Read = Reading, and Writ = Writing.

small island nation with a community-based economy. It is likely that advantages of maternal education are transferred to the whole community rather than biological children only and thus the association may not be seen. Similar results were observed when using the International Development and Early Learning Assessment (IDELA) in Ethiopia. A direct assessment of children aged 3–6 years, maternal education did not predict IDELA scores in this context (Wolf et al., 2017). Stimulating home environments have positive effects on ECD and this pattern was also evident among eHCI scores in all countries, with the strongest

associations observed for literacy and numeracy. This finding was aligned with analysis of the CREDI in Brazil amongst children aged 0–2 years (Altafim et al., 2018).

The strongest associations with direct assessment of literacy and numeracy in Lao PDR were observed for eHCI Numeracy, Reading, and Writing domains as expected. Few similar ECD measures have published concurrent validity evidence with the IDELA an exception. Specifically, the IDELA and the Ages and Stages Questionnaire (ASQ) were used to measure development of children aged 4–5 years in Bangladesh, with
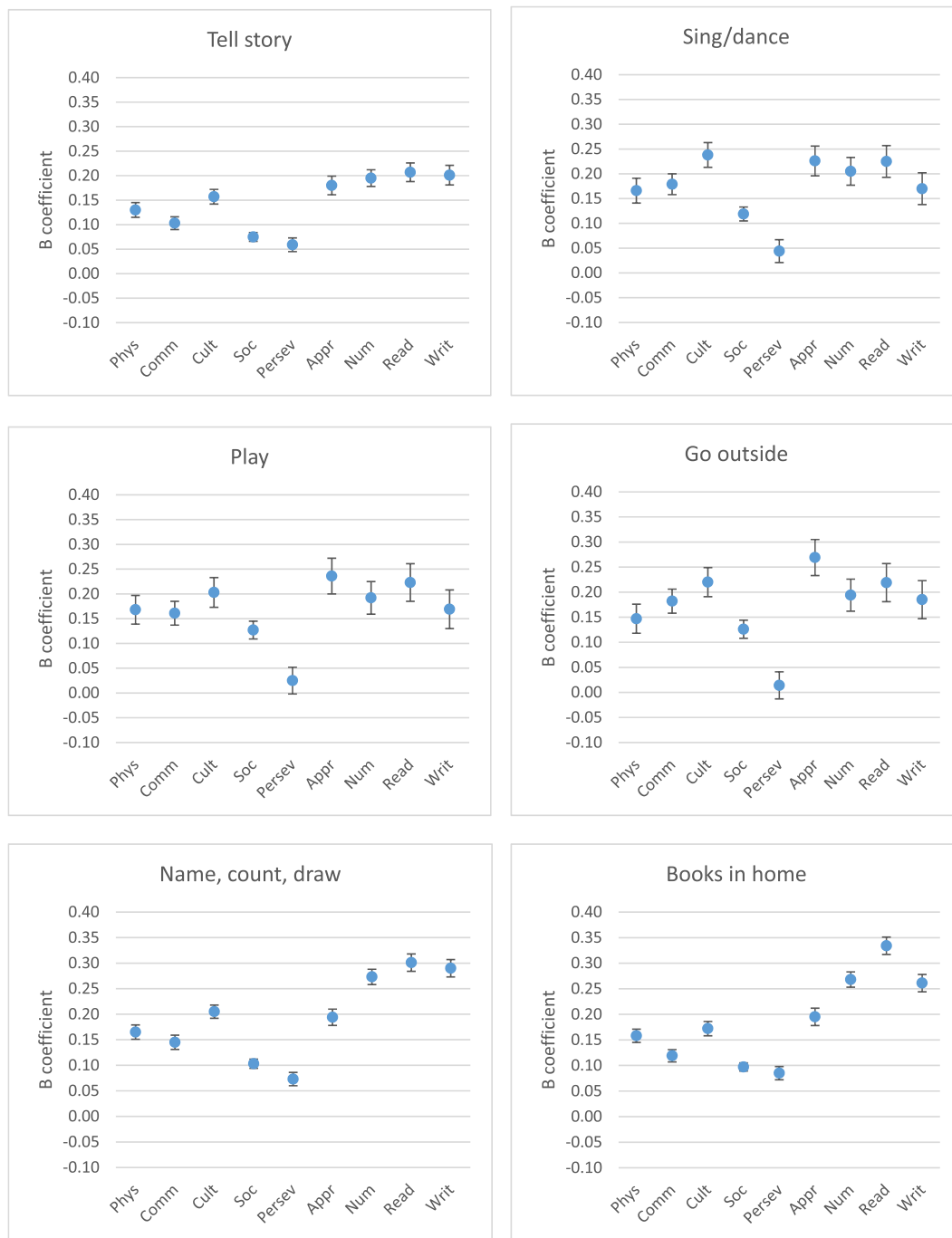
Note. Female, stunted, attended preschool, home learning environment yes = 1; male, not stunted, did not attend preschool, home learning environment items no = 0. Phys=Physical Health, Comm=Verbal Communication, Cult=Cultural Knowledge, Soc=Social and Emotional, Persev=Perseverance, Appr=Approaches to Learning, Num=Numeracy, Read=Reading, and Writ=Writing.

Fig. 2. (*continued*).

results indicating medium correlations between respective IDELA and ASQ domains when examining children's literacy (r = 0.36) and larger correlations between domains measuring numeracy (r = 0.48) (Pisani et al., 2018). Concurrent validity of eHCI scores were stronger than those reported for the IDELA. Together, results provide evidence for the concurrent validity of the eHCI in this setting.

4.2. Implications of findings

Inclusion of ECD in the Sustainable Development Agenda raises issues regarding how this goal should be monitored. Relative to other measures of ECD, the eHCI can be implemented feasibly in low resource settings, captures development across domains and abilities, and produces information relevant to local policy and practice. Results demonstrate that the eHCI discriminated between the development of children and captured the intended aspects of ECD within a range of
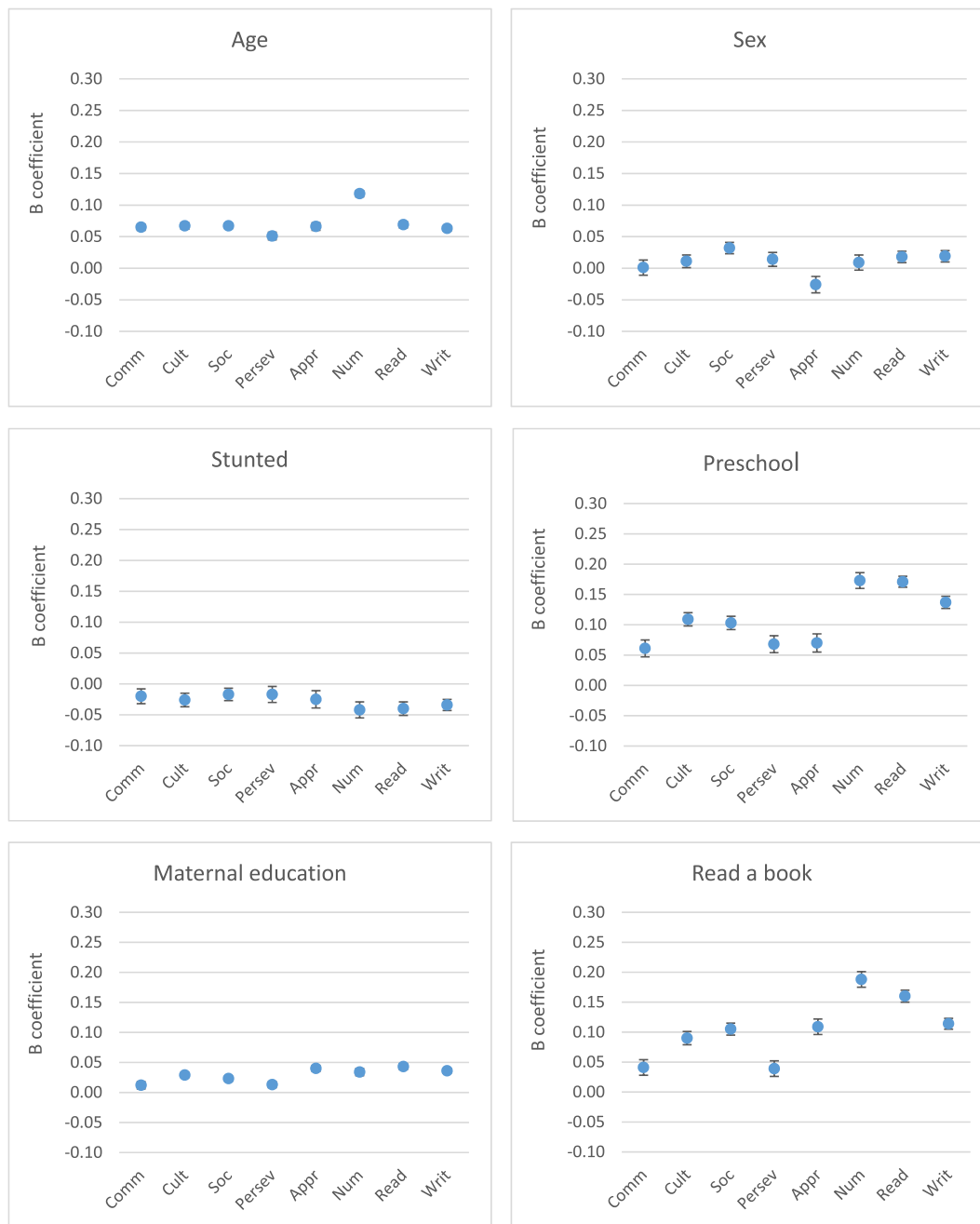
Fig. 3. Discriminant validity: linear regression coefficients and 95% confidence intervals of eHCI domain scores on demographic and contextual variables in Lao PDR (n = 7493, 2015/16).

Note: The Lao PDR version of the eHCI does not include a Physical Health domain. Information regarding books in the home were not collected in Lao PDR. Female, stunted, attended preschool, home learning environment items yes = 1; male, not stunted, did not attend preschool, home learning environment items no = 0. Comm = Verbal Communication, Cult = Cultural Knowledge, Soc = Social and Emotional, Persev = Perseverance, Appr = Approaches to Learning, Num = Numeracy, Read = Reading, and Writ = Writing.

LMICs. Together with previous research (Sincovich et al., 2019), findings indicate the tool can provide valid measurement of ECD in diverse contexts.

Although associations observed among eHCI domains and with child and family characteristics were relatively consistent overall, some variation in results across countries highlights the context-specific nature of ECD measurement. For instance, varied strength of the association between caregiver-child interactions and eHCI scores could be a reflection of cultural and/or contextual factors, including those related to caregiving practices and early years service provision. This lends

support to the need for ECD measures to produce information that reflects local settings. Global comparability and cultural neutrality are the focus for tracking progress toward SDG 4.2 (Richter et al., 2019), however this approach will not have the sensitivity to capture change in ECD as a result of local interventions or policy shifts, and will not reflect aspects of ECD important to the local context. Experts in ECD measurement continue to be challenged by striking a balance between producing globally comparable data and producing information relevant to local policy and practice (Rao, Mirpuri, Sincovich, & Brinkman, 2020).
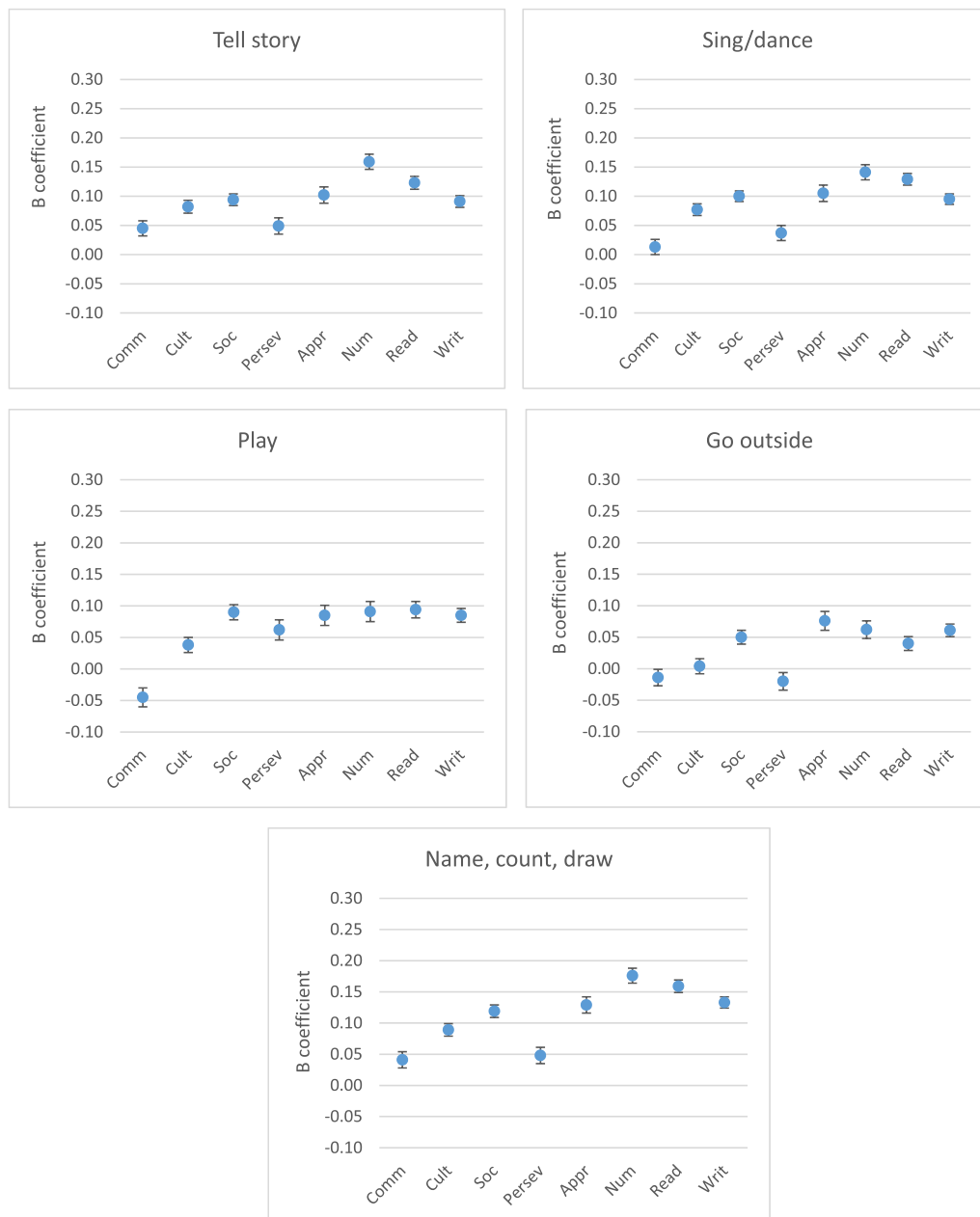
Note: The Lao PDR version of the eHCI does not include a Physical Health domain. Information regarding books in the home were not collected in Lao PDR. Female, stunted, attended preschool, home learning environment items yes = 1; male, not stunted, did not attend preschool, home learning environment items no = 0. Comm=Verbal Communication, Cult=Cultural Knowledge, Soc=Social and Emotional, Persev=Perseverance, Appr=Approaches to Learning, Num=Numeracy, Read=Reading, and Writ=Writing.

Fig. 3. (*continued*).

5. Conclusion

Results demonstrate the eHCI is psychometrically robust in diverse country contexts and could enable the evaluation of early years policies and programs, as well as monitoring of children's development to track progress towards the Sustainable Development Agenda in LMICs. Existing ECD measurement tools range from short adult-report tools designed for population monitoring (e.g. MICS-ECDI), to detailed, multi-domain direct assessment batteries designed to aid program evaluation. Findings indicate the eHCI is suitable for both applications. Indeed, the eHCI is a feasible and valid population monitoring measure when applied through either a census or sample approach. The eHCI is free, requires minimal implementation resources, captures development across domains and abilities, and allows local culture and context to be reflected. Results presented in this paper together with previously published evidence demonstrate that the tool is able to provide valid measurement of ECD. The next step in assessing the validity of the eHCI is exploring how well it predicts later outcomes of interest such as academic achievement and social and emotional skills.
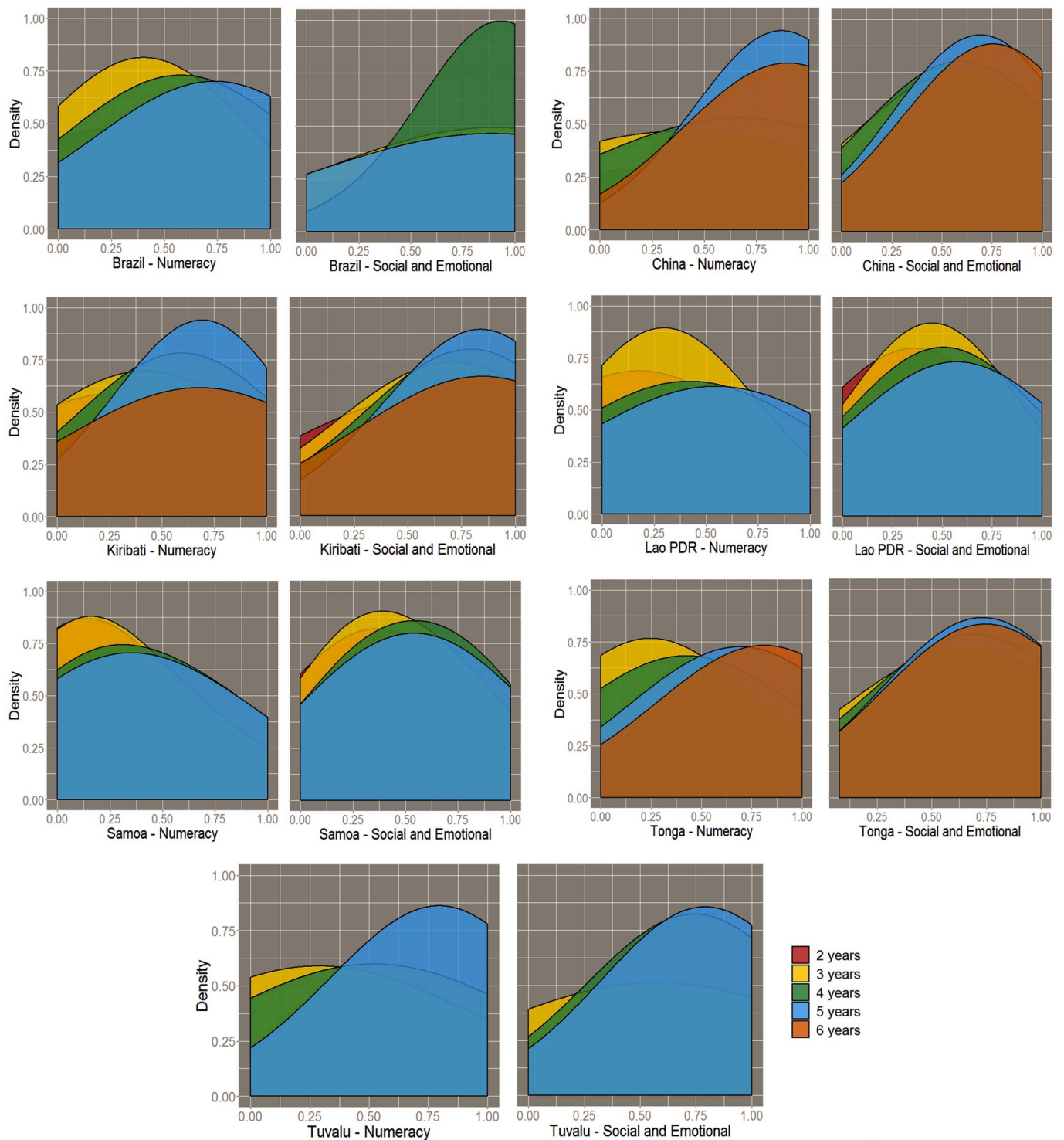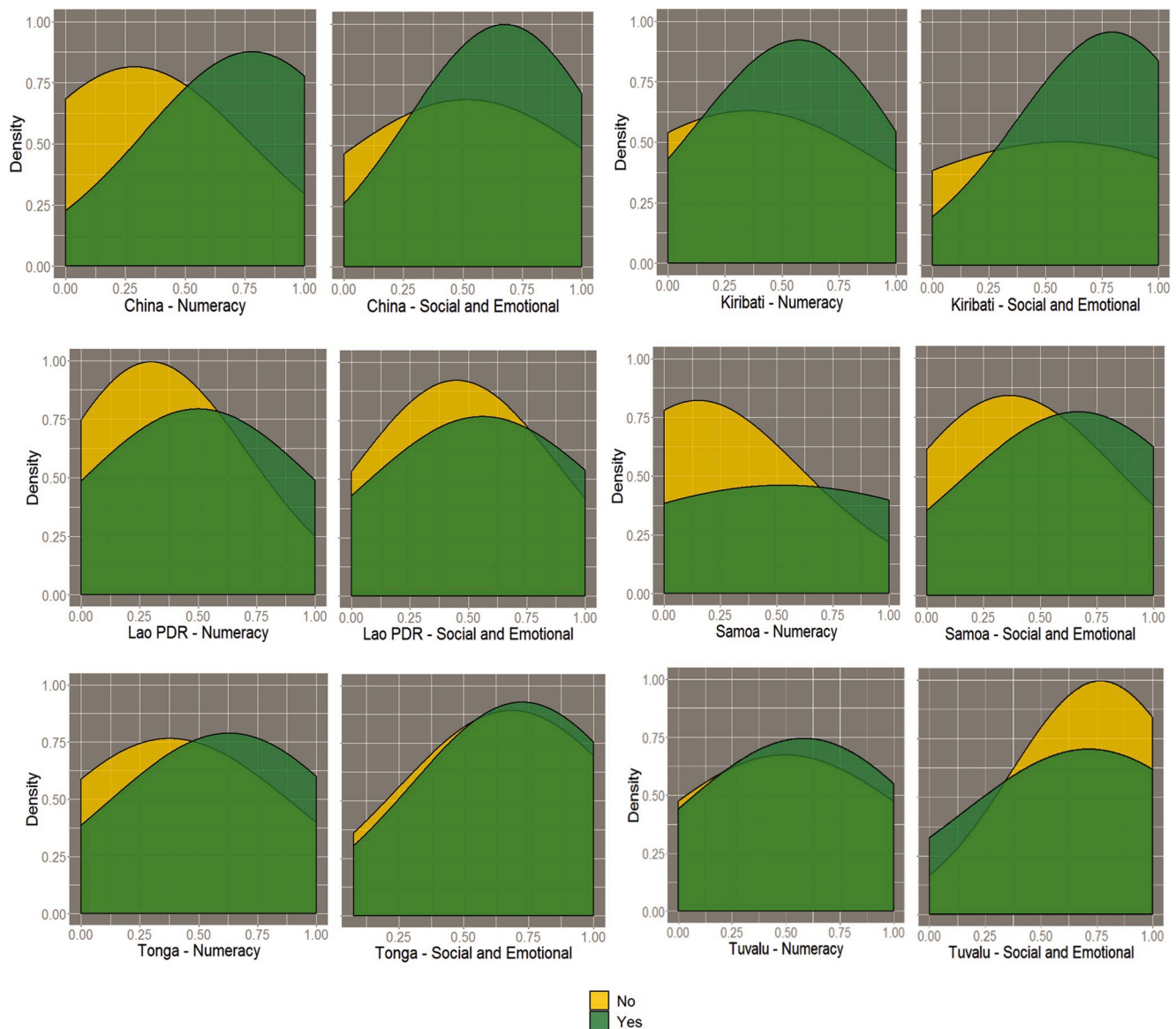
Note. X-axis = eHCI domain score, y-axis = proportion of children e.g. in Brazil the largest proportion of 3-year-olds scored approximately 0.40 on the Numeracy domain.

Fig. 4. Discriminant validity: distribution of eHCI Numeracy and Social and Emotional Skills domains by age (years) in 7 LMICs.
Note. X-axis = eHCI domain score, y-axis = proportion of children e.g. in Brazil the largest proportion of 3-year-olds scored approximately 0.40 on the Numeracy domain.

Declaration of competing interest

We declare no competing interests.

Role of the funding source

Note. X-axis = eHCI domain score, y-axis = proportion of children e.g. in China the largest proportion of children who attended preschool scored approximately 0.75 on the Numeracy domain. Results are not presented for Brazil as 100% of the sample were attending preschool.

Fig. 5. Discriminant validity: distribution of eHCI Numeracy and Social and Emotional Skills domains by preschool attendance in 7 LMICs.
Note. X-axis = eHCI domain score, y-axis = proportion of children e.g. in China the largest proportion of children who attended preschool scored approximately 0.75 on the Numeracy domain. Results are not presented for Brazil as 100% of the sample were attending preschool.

Table 3
Concurrent validity: correlations among eHCI domain scores and literacy and numeracy direct assessment scores in Lao PDR (n = 7493, 2015/16).

	Comm	Cult	Soc	Persev	Appr	Num	Read	Writ
Total numeracy score	.18	.29	.33	.22	.24	.50	.40	.37
Total literacy score	.06	.24	.26	.18	.16	.42	.39	.39

Notes: $p < .05$ for all correlations (Spearman's rho). Phys = Physical Health, Comm = Verbal Communication, Cult = Cultural Knowledge, Soc = Social and Emotional, Persev = Perseverance, Appr = Approaches to Learning, Num = Numeracy, Read = Reading, and Writ = Writing.

had full access to all data in the study and had final responsibility for the decision to submit for publication.

Research ethics statement

The current study is a secondary analysis of pre-existing, de-identified data and thus was deemed exempt from requiring ethical review by

the University of Adelaide Human Research Ethics Committee.

CRediT authorship contribution statement

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100613.

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