COMPARISON OF HEIGHT MEASURING INSTRUMENTS FOR CHILDREN USED IN TWO MUNICIPALITIES OF LAGUNA, PHILIPPINES

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Abstract. Stunting is a global nutritional problem including in the Philippines. Regardless of location, doubts on accuracy and reliability of equipment used in measuring stunting exist. Standardized measuring procedures and equipment should be used to ensure accuracy, reliability and minimal measurement errors. Four height measuring equipment, namely, Allen's Stick, Aluminum-Acrylic Height Board, Stadiometer and Wooden Height Board, were assessed for accuracy and reliability of height determinations obtained from three end-user pairs. Trials were conducted in two municipalities in Laguna, Philippines, by 12 community health and nutrition workers as end-users. Height/length values of randomly selected children (n = 40), 6-71 months of age, were achieved with high accuracy and degree of reliability for both inter- and intra-measurers using the Wooden Height Board, but the other three height measurement equipment were equally acceptable provided adequate training was provided on the procedures recommended by the manufacturers. The relatively high weight of the Wooden Height Board was offset by its low production cost.

Keywords: accuracy, anthropometry, reliability, technical error of measurement

INTRODUCTION

Height/length is internationally recognized as one of the indicators of nutritional status and health in a population (WHO, 2010). Measuring height/length is important to determine if a child is growing normally. Stunting is defined as height-for-age < –2 SD of the WHO Child Growth Standards median (WHO, 2010). Percent stunted children reflects cumulative effects of undernutrition and infections before and after birth, indicating poor environmental conditions and long-term social inequalities, which ultimately restrict a child's growth potential (WHO, 2010; de Onis and Branca, 2016). Globally, it is estimated 161 million children under five years of age are stunted, about half of whom live in Asia (de Onis and Branca, 2016).

In the Philippines, stunting continues to be a public health problem. The 2013 National Nutrition Survey (NNS) of the Food and Nutrition Research Institute showed 30.3% and 29.9% of children <5 and 5-10 years of age, respectively, are

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stunted (DOST-FNRI, 2016) and based on WHO prevalence cut-off values, this situation is considered a serious public health problem (WHO, 2010). The effects of stunting, *eg*, morbidity, cognition and productivity, are experienced at individual, family and society levels. Causes of stunting are due to environmental, socio-economic and cultural factors, all of which are believed to be universal (WHO, 2010).

Thus, it is important to ensure the tool employed in determining a child length/height value is accurate and reliable if this parameter is to be of use in evaluating a child adequate growth and identifying and addressing growth problems (de Onis and Branca, 2016). Imprecise measurements can lead to misclassification of height/length, resulting in unnecessary implementation of intervention procedures, incorrect referrals and unwarranted parents' concern. Inaccuracies in length/height measurement conducted by community health and nutrition workers were reported particularly in the Philippines (Briones *et al,* 2017**).** This can be attributed to heavy weight of the wooden height board, difficulty in conveying the wooden height board in house visits for mass weighing and measurement of length/height, non-adherence to standard protocol of taking height measurement, inadequate training, and incorrect reading and interpretation of height data (Gordoncillo *et al,* 2005)**.**

The material of height measurement equipment is usually wood. In the Philippines, the recommended measuring equipment for use by community health and nutrition workers is the wooden height board (NNC, 2018). Health workers are mandated to conduct house-to-house anthropometric measurements of children and provide basic nutrition education and counselling (NNC, 2012a), similar to other countries such as Kenya (Mwangome *et al*, 2012). However, as wooden height board is heavy, alternative materials for use in fabricating lightweight height boards, such as plastic and metal, have been explored. Cambodia and Indonesia are experimenting the use of durable plastic that can be easily carried by community health workers (Diani and Kapoor, 2018; Save the Children Cambodia, 2015).

Using appropriate height measuring equipment is a major factor in minimizing measurement errors (Gibson, 2005; de Onis and Branca, 2016). hence, three height/length measuring equipment of different construction materials, namely, Allen's stick made of steel, aluminum-acrylic height board, and stadiometer made of medical plastic were compared with National Nutrition Council (NNC) wooden height/length board to evaluate the performance of these four measuring equipment following a set of criteria, and to assess the accuracy and reliability of height readings obtained by end-user pairs (nutrition and health workers).

MATERIALS AND METHODS

Study design and test sites

This field trial was conducted in two municipalities, Bay and Sta. Rosa, Laguna Province, Philippines. The study sites were selected based on a set of criteria: population size, income and accessibility.

Study participants

Community nutrition and health workers (n=12), referred as end-users, were participants in measuring children's height/length in their respective community. In each study site, there were three end-user pairs, each composed of a community health and a nutrition worker with one designated as main measurer and the other served as assistant measurer. Each

end-user pair measured the height/length of children in a stationary and mobile setting. In the former, end-users conducted measurement either in a community hall or the community health station as the children arrived, or in the latter, end-users went going to each of the children's house to obtain the measurement. In each study site, children (n = 20; 10 of 6-23 months and 10 of 24-71 months of age) were randomly selected from the master list of the Operation Timbang Plus (OPT+), where height measurement was included (NNC, 2012a). Sample size was based on the number applied in standardization of anthropometric equipment and in field trial studies, in which accuracy and reliability of equipment can be estimated (Voss and Bailey, 1994).

The research protocols were approved by The National Ethics Committee of the Philippine Council for Health Research and Development, Department of Science and Technology, the Philippines (NEC Code 2017-001). Prior written consent was obtained from parents/legal guardians of all participating children.

Height/length measuring equipment

Four height/length measuring equipment were used: NNC wooden height board, approved by the National Nutrition Council Governing Board (NNC-GB), locally made by various local government units in the Philippines; Allen's stick made of aluminum (developed by a Filipino doctor); aluminum-acrylic height board (also developed by a Filipino doctor); and stadiometer made of medical plastic. Each equipment was verified in terms of weight, height, material, storage, packaging, transportation, safety, durability, portability, and universality before use in the survey. This was carried out by trained personnel from the Provincial Health Office by comparing with a calibrated steel rule (S.N. 2013-1-0349K-46), according to the NNC Governing Board Resolution No. 3, s. 2012 (NNC, 2012b).

Data collection

The established procedure for measuring children's height/length was as followed (WHO, 2008). Measurements were consistently taken in the morning to account for diurnal variation as children's height is greater in the morning and declines (up to a cm) during the course of the day due to compression of fibrous intervertebral cartilaginous disks (Berdanier *et al*, 2013). Recumbent length was measured for children <2 years of age and standing height for children ≥2 years of age. For each equipment, the same procedure was employed to measure height/length, *ie* height board was mounted at a right angle between a level floor and a straight, vertical surface such as a wall or pillar, or the length board was placed on a flat, stable surface such as a table. Before measurement, shoes, hair clips, braids, or head covering were removed.

Each end-user pair measured height/length twice in both settings. The recommended protocol for recording measurements established by BMI Task Force was followed (WHO, 2010). If the difference between the two readings was <0.5 cm, then the first reading was recorded; however, if the difference was >0.5 cm, a third measurement was taken and the measurement that deviated the most was dropped and the two closest values recorded were considered (ACHI, 2018). In order to avoid bias or being influenced by the first measurement when taking a second measurement, each end-user pair was asked to make the second round of measurements only after all measurements were completed.

Before the actual tests, end-users were trained on the correct use of each equipment. A mock trial exercise was conducted to forestall mistakes that could occur during taking measurements in a community setting.

Verification of equipment

Trained personnel from Laguna Provincial Health Office verified the accuracy of the four equipment by comparing with a calibrated steel rule with S.N. 2013-1-0349K-46. The verification was conducted twice – before the height/length measurements in the stationary setting and before the measurements in the mobile setting.

Data analysis

Descriptive statistics and percent distributions were employed to describe the characteristics of parents/guardians and end-users. As end-users vary from one community to another, reliability of the readings was evaluated, *ie*, degree at which different end-users agrees with their assessments, using intra-class correlation coefficient (ICC), with a negative coefficient indicating no reliability; >0-<0.2, slight reliability; 0.2-<0.4, fair reliability; 0.4-<0.6, moderate reliability; 0.6-0.8, substantial reliability; and 0.8-1.0, almost perfect reliability. Inter-measurer reliability test was used to determine if the readings measured by two end-user pair on the same set of children were consistent and in agreement. Intra-measurer reliability was accepted if measurements performed by the same end-user pair on the same set of children at two different times were in agreement. In addition, a reliability index based on the Technical Error of Measurement (TEM), *ie*, variability between repeated measures was calculated and the lower the TEM value, the more reliable it is. Relative TEM (%TEM) was generated to determine if the error is within acceptable range, *ie*, error in readings between two measurements (intra-measurer) is considered acceptable if %TME is <1.5%, and error in readings between two end-pair users (inter-measurer) acceptable if %TME is <2%. Coefficient of variation (CV) of ≤ 5% indicates good performance (Jamaiya *et al*, 2010). Difference in mean height/length readings between two end-user pairs and two measurements (at different times) was evaluated using *t*-test for paired samples, and also used to analyze validity of test the three-alternative equipment) against NNC wooden height board.

RESULTS

Profile of end-users

The community health and nutrition workers (CHNWs) from rural area (Bay) and from urban area (Sta. Rosa) had mean age of 49 and 45 years, respectively. CHNWs from Bay were in service longer than those from Sta. Rosa (mean of 7 and 5 years, respectively) and 50% and 83% from Bay and Sta. Rosa were high school graduates.

Comparison of the four types of height/length measurement equipment

Allen's Stick (3.3 kg) was the lightest, followed by Stadiometer (3.4 kg), then Aluminum-Acrylic and NNC Wooden Height Board (both 5.6 kg). Stadiometer was highest (213.5 cm), followed by Allenstick (151.7 com), NNC Wooden Board (146.6 cm) and Aluminum-Acrylic Height Board (131.9 cm).

The Allen's Stick has no sharp edges or heavy head board, making it safe for use; however, contains a feature allowing a switch of the headboard to a footboard when measuring recumbent length, which might be confusing to CHNWs without proper training.

The Stadiometer appeared to be safe for use as it is made of a light-weight material and has no sharp edges or heavy headboard that is also smooth-sliding. However, assembling and disassembling the equipment took time, but it also comes with a water-resistant bag making for easy storage and transportation. However, it cannot be used to measure infants' recumbent length given its design.

The Aluminum-Acrylic Height Board has a friendly appearance making it appealing to children and their parents/guardians, but its foldable feature and material may cause it to become a hazard, *ie*, child can hit his/her head on the board, acrylic foot board may easily be broken if using by too many children . However, it allows for a readable gradation. It comes with knapsack-style bag that is easy to transport despite its weight and bulky structure.

The Wooden Height Board with its relatively heavy headboard was deemed unsafe for use with children; in addition, it has a lock, which may affect measurement accuracy as when locked, the headboard drops a few mm. It is difficult to operate because its heavy headboard becomes more of an obstruction to the user, particularly in reading the height/length value. Because the headboard is heavy, it can also intimidate parents/guardians who may perceive it as unsafe.

In terms of manufacturing cost, the Wooden Height Board could easily be produced locally as the building material is readily available. Aluminum-Acrylic Height Board, Allen's Stick and Stadiometer were manufactured by local companies, the latter being the most expensive, followed by Allen's Stick, then Aluminum-Acrylic Height Board and Wooden Height Board being the cheapest.

Inter-measurer reliability and accuracy

In Bay municipality, a high degree of reliability in measurements between end-user pairs were observed with all four instruments (Table 1). Errors in measurement were within acceptable limits except when NNC Wooden Height Board and Aluminum-Acrylic Height Board in stationary setting were used (computed percent TME >2%). Inconsistency between readings by end-user pair 2 and 3 using the Aluminum-Acrylic and NNC Wooden Height Boards in a stationary setting, and between end-user pair 1 and 3 in using the latter equipment were also evident in their computed CV values (>10%, the highest acceptable value for reliability).

Accuracy was attained in measurements between end-user as differences of their absolute mean values are not statistically significant, except between end-user pair 1 and 2 using NNC Wooden Height Board. Significant mean differences in readings were also noted for end-user pair 1 and 3 using the NNC Wooden Height Board in the mobile setting, and between end-user pair 2 and 3 using the Aluminum-Acrylic Height Board in the stationary setting. However, no inconsistencies and disagreements among end-user pairs in Bay municipality were observed when Allen's Stick and Stadiometer were used. Furthermore, based on computed percent TME values, Stadiometer could be considered the most reliable in the mobile setting followed by Allen's Stick, and vice versa in the stationary setting.

Likewise, height/length readings of end-user pairs in Sta. Rosa municipality were reliable as revealed in their almost perfect ICC values (Table 1). This was supported by low values of TME and acceptable values of percent TME and CV. Height readings of two end-user pairs were also accurate, as shown by absence of

Table 1
Inter-measurer reliability of height/length measurements of children <1-71 months of age performed by three end-user pairs in Bay and Sta. Rosa municipalities, Laguna Province, Philippines.

Measuring instrument	Bay municipality								Sta. Rosa municipality							
	End-user pair	Mean (cm) (n = 20)		p-value*	ICC	TME	Percent TME	CV (%)	End-user pair	Mean (cm) (n = 20)		p-value*	ICC	TME	Percent TME	CV (%)
		M1[a]	M2[b]							M1[a]	M2[b]					
Mobile setting																
Allen's stick	1 and 2	85.1	84.9	0.217	0.999	0.25	0.30	0.29	1 and 2	91.6	91.8	0.174	0.997	0.29	0.32	0.31
	1 and 3	85.1	84.8	0.086	0.999	0.24	0.28	0.25	1 and 3	91.6	91.4	0.422	0.997	0.34	0.37	0.38
	2 and 3	84.9	84.9	0.726	0.999	0.32	0.38	0.39	2 and 3	91.8	91.4	0.048	0.996	0.38	0.41	0.35
Aluminum-acrylic	1 and 2	83.9	83.8	0.491	0.998	0.54	0.64	0.66	1 and 2	90.9	90.8	0.860	0.997	0.29	0.32	0.33
	1 and 3	83.9	84.0	0.664	0.999	0.26	0.31	0.32	1 and 3	90.9	90.7	0.204	0.997	0.31	0.35	0.34
	2 and 3	83.8	84.0	0.272	0.998	0.45	0.53	0.53	2 and 3	90.8	90.7	0.319	0.996	0.38	0.42	0.42
Stadiometer[c]	1 and 2	97.3	97.0	0.168	0.998	0.08	0.08	0.15	1 and 2	99.5	99.4	0.326	0.997	0.08	0.08	0.16
	1 and 3	97.3	97.0	0.066	0.998	0.09	0.09	0.14	1 and 3	99.5	99.3	0.290	0.995	0.13	0.14	0.27
	2 and 3	97.0	96.9	0.483	0.999	0.04	0.04	0.08	2 and 3	99.4	99.3	0.604	0.999	0.05	0.05	0.10
NNC wooden board	1 and 2	83.9	84.5	0.011	0.998	0.48	0.57	0.42	1 and 2	91.5	91.3	0.113	0.995	0.43	0.47	0.44
	1 and 3	83.9	84.9	0.023	0.992	2.04	2.42	1.93	1 and 3	91.5	91.2	0.100	0.996	0.43	0.47	0.47
	2 and 3	84.5	84.9	0.294	0.992	1.89	2.23	2.21	2 and 3	91.3	91.2	0.921	0.999	0.10	0.11	0.12
Stationary setting																
Allen's stick	1 and 2	84.9	85.0	0.859	0.999	0.31	0.37	0.39	1 and 2	91.3	91.6	0.133	0.997	0.27	0.30	0.28
	1 and 3	84.9	84.8	0.696	0.999	0.37	0.43	0.45	1 and 3	91.3	91.5	0.425	0.994	0.66	0.72	0.74
	2 and 3	85.0	84.8	0.369	0.999	0.14	0.17	0.17	2 and 3	91.6	91.5	0.897	0.989	1.08	1.18	1.24
Aluminum-acrylic	1 and 2	83.9	85.0	0.077	0.987	3.00	3.56	3.17	1 and 2	91.1	91.0	0.969	0.996	0.37	0.40	0.42
	1 and 3	83.9	83.1	0.241	0.981	4.25	5.09	4.97	1 and 3	91.1	91.2	0.774	0.991	0.93	1.02	1.07
	2 and 3	84.9	83.1	0.040	0.966	7.44	8.86	7.42	2 and 3	9110	91.2	0.784	0.992	0.85	0.94	0.98

Table 1 (Continued)

Measuring instrument	Bay municipality								Sta. Rosa municipality							
	End-user pair	Mean (cm) ($n = 20$)		p-value*	ICC	TME	Percent TME	CV (%)	End-user pair	Mean (cm) ($n = 20$)		p-value*	ICC	TME	Percent TME	CV (%)
		M1[a]	M2[b]							M1[a]	M2[b]					
Stadiometer[c]	1 and 2	97.9	97.1	0.219	0.978	0.96	0.98	1.83	1 and 2	99.3	99.4	0.453	0.999	0.03	0.03	0.06
	1 and 3	97.9	97.2	0.217	0.982	0.79	0.81	1.51	1 and 3	99.3	99.1	0.195	0.998	0.07	0.07	0.13
	2 and 3	97.1	97.2	0.696	0.998	0.07	0.07	0.15	2 and 3	99.4	99.1	0.403	0.998	0.07	0.07	0.15
NNC wooden board	1 and 2	84.5	83.7	0.003	0.996	0.88	1.04	0.69	1 and 2	91.2	91.6	0.050	0.995	0.52	0.57	0.49
	1 and 3	84.5	86.0	0.275	0.943	17.1	20.04	19.8	1 and 3	91.2	91.1	0.962	0.996	0.40	0.44	0.46
	2 and 3	83.7	86.0	0.123	0.930	21.2	25.07	23.2	2 and 3	91.6	91.1	0.022	0.996	0.40	0.44	0.35

[a]First mesurement. [b]Second measurement. [c]Children 24-71 months of age; Bay municipality ($n = 20$), Sta. Rosa municipality ($n = 20$),
*Significant at p-value <0.05. CV, coefficient of variation; ICC, intra-class correlation coefficient; TME, technical error of measurement.

significant difference in mean readings, except between end-user pair 2 and 3 using Allen's Stick in the mobile setting and NNC Wooden Height Board in the stationary setting. Mean difference in height reading of end-user pair 2 is significantly higher than end-user pair 1. Overall, end-users achieved highest degree of reliability (based on TME) when Stadiometer was used.

Intra-measurer reliability and accuracy

In Bay municipality, differences between two height measurements were not significantly different except for end-user pair 3 using Aluminum-Acrylic Board in the stationary setting (Table 2). Nevertheless, all end-user pairs were reliable in their two measurements, evidenced by small TME and acceptable percent TME and CV values, with the highest reliability obtained using the Stadiometer. High degree of intra-measurer reliability was observed, as demonstrated by their ICC values indicating perfect agreement.

Similarly, in Sta. Rosa municipality, height measurements of end-user pairs were consistent between the two measurements except in the case of end-user pair 3 using Aluminum-Acrylic Board in the mobile setting when mean height measurement was higher in the first than second measurement. Intra-end-user pair measurers showed reliable results using all four height measuring instruments. Percent TME and CV values were all within acceptable limits and nearly all ICC values (except for Aluminum-Acrylic by Pair 3 with ICC of 0.999) had values of 1, indicating perfect agreement between two measurements. Similar with previous analysis, end-user pairs who used the Stadiometer produced the most reliable height readings.

Table 2
Intra-measurer reliability of height/length measurements of children <1-71 months of age using four instruments by three end-user pairs in Bay and Sta. Rosa municipalities, Laguna Province, Philippines.

Measuring instrument	Bay municipality								Sta. Rosa municipality							
	End-user pair	Mean (cm) ($n = 20$) M1[a]	Mean (cm) ($n = 20$) M2[b]	*p*-value*	ICC	TME	Percent TME	CV (%)	End-user pair	Mean (cm) ($n = 20$) M1[a]	Mean (cm) ($n = 20$) M2[b]	*p*-value*	ICC	TME	Percent TME	CV (%)
Mobile setting																
Allen's stick	1	85.1	85.1	1.000	1.000	0.03	0.03	0.04	1	91.6	91.5	0.905	1.000	0.02	0.02	0.02
	2	84.9	84.9	0.117	1.000	0.03	0.02	0.2	2	91.8	91.9	0.314	1.000	0.02	0.02	0.02
	3	84.8	84.8	0.839	1.000	0.02	0.03	0.03	3	91.4	91.3	0.491	1.000	0.05	0.05	0.06
Aluminum-acrylic	1	83.9	83.9	0.895	1.000	0.01	0.02	0.03	1	90.9	91.0	0.673	1.000	0.01	0.01	0.01
	2	83.8	83.7	0.921	1.000	0.02	0.03	0.03	2	90.9	90.8	0.757	1.000	0.02	0.02	0.03
	3	84.1	84.0	0.076	1.000	0.02	0.02	0.02	3	90.6	90.8	0.012	0.999	0.05	0.06	0.04
Stadiometer[c]	1	97.3	97.2	0.522	1.000	0.01	0.01	0.03	1	99.5	99.6	0.210	1.000	0.01	0.01	0.02
	2	97.1	97.0	0.134	1.000	0.01	0.01	0.03	2	99.3	99.4	0.083	1.000	0.01	0.01	0.02
	3	96.9	97.0	0.173	1.000	0.01	0.01	0.01	3	99.3	99.2	0.520	1.000	0.01	0.01	0.01
NNC wooden board	1	83.9	84.0	0.452	1.000	0.05	0.06	0.06	1	91.6	91.5	0.873	1.000	0.04	0.04	0.04
	2	84.5	84.5	0.658	1.000	0.00	0.04	0.04	2	91.0	91.2	0.739	1.000	0.03	0.04	0.03
	3	84.9	85.0	0.208	1.000	0.04	0.05	0.05	3	91.1	91.2	0.379	1.000	0.02	0.02	0.02
Stationary setting																
Allen's stick	1	85.0	84.9	0.235	1.000	0.01	0.03	0.03	1	91.3	91.4	0.684	1.000	0.02	0.03	0.03
	2	84.9	85.0	0.572	1.000	0.02	0.02	0.02	2	91.6	91.5	0.739	1.000	0.02	0.02	0.02
	3	84.9	84.8	0.391	1.000	0.04	0.05	0.05	3	91.5	91.4	0.761	1.000	0.01	0.01	0.01
Aluminum-acrylic	1	84.0	83.8	0.075	1.000	0.07	0.09	0.08	1	91.1	91.1	1.000	1.000	0.02	0.02	0.02
	2	84.9	84.8	0.460	1.000	0.03	0.03	0.03	2	91.0	91.1	0.628	1.000	0.03	0.03	0.03
	3	83.1	83.2	0.024	1.000	0.03	0.03	0.02	3	91.0	91.0	1.000	1.000	0.02	0.02	0.02

Table 2 (Continued)

Measuring instrument	Bay municipality							Sta. Rosa municipality						
	End-user pair	Mean (cm) (n = 20)		p-value*	ICC	TME	Percent TME	CV (%)	End-user pair	Mean (cm) (n = 20)		p-value*	ICC	TME	Percent TME	CV (%)
		M1[a]	M2[b]							M1[a]	M2[b]					
Stadiometer[c]	1	97.9	97.9	1.000	1.000	0.01	0.01	0.01	1	99.4	99.3	0.462	1.000	0.01	0.01	0.01
	2	97.1	97.1	0.662	1.000	0.01	0.01	0.01	2	99.2	99.2	1.000	1.000	0.01	0.01	0.01
	3	97.3	97.2	0.286	1.000	0.02	0.02	0.04	3	99.0	99.1	0.111	1.000	0.01	0.01	0.01
NNC wooden board	1	84.5	84.5	0.549	1.000	0.05	0.06	0.06	1	91.1	91.2	0.376	1.000	0.04	0.05	0.05
	2	83.7	83.7	1.000	1.000	0.05	0.06	0.06	2	91.6	91.5	0.662	1.000	0.02	0.02	0.02
	3	86.0	85.9	0.153	1.000	0.11	0.13	0.12	3	91.1	91.2	0.220	1.000	0.02	0.02	0.02

[a]First mesurement. [b]Second measurement. [c]Children 24-71 months of age; Bay municipality (n = 20), Sta. Rosa municipality (n = 20), *Significant at p-value <0.05 Significant at p-value <0.05. CV, coefficient of variation; ICC, intra-class correlation coefficient; TME, technical error of measurement.

Intra-measurer reliability assessment was further performed between mobile and stationary settings. There was a high degree of reliability between these two settings as demonstrated by their close to perfect ICC values (both in Bay and Sta. Rosa municipalities) (Table 3). Low TME and acceptable values of percent TME and CV likewise were indicative of consistent readings between mobile and stationary settings, except for end-user pair 2 and 3 in Bay municipality when Aluminum-Acrylic and NNC Wooden Height Boards were employed. These end-user pairs produced percent TME values exceeding acceptable limits. The inconsistency of end-user pair 3 while using NNC Wooden Height Board could be further observed in the CV, exceeding the acceptable 5% value. In addition, readings of end-user pair 2 obtained from Aluminum-Acrylic and NNC Wooden Height Boards are significantly different in both settings, as with end-user pair 1 readings from the latter Board. In Sta. Rosa municipality, however, all readings were consistent, precise, and reliable as indicated by the different statistical measurements.

Accuracy and consistency among the four height measuring instruments

Using NNC Wooden Height Board as reference measuring instrument, in the case of length measurements of children <1-23 months of age, mean difference in reading employing Allen's Stick is significantly higher than reference equipment in both settings (Table 4). The Aluminum-Acrylic Board produced a significantly lower mean difference

Table 3
Intra-measurer accuracy of three end-user pairs using four instruments in measuring height/length of children <1-71 months old in Bay and Sta. Rosa municipalities, Laguna Province, Philippines.

Measuring instrument	End-user pair	Mean (cm)		*p*-value*	ICC	TME	Percent TME	CV (%)
		Mobile setting	Stationary setting					
Bay municipality (*n* = 20)								
Allen's stick	1	85.1	84.9	0.224	0.999	0.21	0.25	0.24
	2	84.9	85.0	0.785	0.999	0.34	0.40	0.42
	3	84.8	84.9	0.971	0.998	0.40	0.47	0.49
Aluminum-acrylic	1	83.9	83.8	0.785	0.998	0.41	0.49	0.52
	2	83.8	84.9	0.050	0.987	3.07	3.64	3.12
	3	84.0	83.1	0.216	0.977	5.23	6.23	6.06
Stadiometer[#]	1	97.3	97.9	0.337	0.976	1.06	1.09	2.17
	2	97.0	97.1	0.626	0.997	0.14	0.15	0.32
	3	96.9	97.2	0.210	0.997	0.12	0.12	0.23
NNC wooden board	1	83.9	84.5	0.037	0.997	0.76	0.91	0.76
	2	84.5	83.7	0.009	0.996	0.97	1.16	0.84
	3	84.9	86.0	0.486	0.933	23.86	23.80	24.40
Sta. Rosa municipality (*n* = 20)								
Allen's stick	1	91.6	91.3	0.177	0.997	0.26	0.29	0.28
	2	91.8	91.6	0.395	0.994	0.56	0.61	0.62
	3	91.4	91.5	0.670	0.991	0.87	0.95	0.99
Aluminum-acrylic	1	90.4	91.1	0.373	0.996	0.36	0.39	0.39
	2	90.9	91.1	0.236	0.997	0.26	0.29	0.28
	3	90.7	91.0	0.301	0.992	0.85	0.94	0.93
Stadiometer[#]	1	99.5	99.3	0.210	0.998	0.07	0.07	0.12
	2	99.4	99.2	0.595	0.997	0.10	0.10	0.22
	3	99.3	99.1	0.327	0.997	0.08	0.08	0.16
NNC wooden board	1	91.5	91.2	0.094	0.994	0.54	0.59	0.54
	2	91.2	91.6	0.124	0.994	0.59	0.64	0.59
	3	91.2	91.1	0.727	0.997	0.27	0.30	0.31

[#]Children 24-71 months of age; Bay municipality (*n* = 20), Sta. Rosa municipality (*n* = 20).
*Significant at *p*-value <0.05. CV=coefficient of variation; ICC – intra-class correlation coefficient; TME – technical error of measurement

Table 4
Inter-equipment accuracy and consistency of height/length measurements of children <1-71 months of age in Bay and Sta. Rosa municipalities, Laguna province, Philippines.

Equipment	Bay municipality (n=20)				Sta. Rosa municipality (n=20)			
	Mobile setting		Stationary setting		Mobile setting		Stationary setting	
	Mean (cm)	p-value*	Mean (cm)	p-value*	Mean (cm)	p-value*	Mean (cm)	p-value*
<1-23 months of age								
Allen's stick	72.7	0.035	72.3	0.001	83.8	0.171	83.4	0.229
Aluminum-acrylic	71.3	0.047	71.2	0.611	83.0	0.034	83.0	0.394
NNC wooden board#	72.0		71.0		83.5		83.2	
24-71 months of age								
Allen's stick	97.2	0.139	97.5	0.002	99.6	0.006	99.5	0.060
Aluminum-acrylic	96.6	0.008	96.5	0.468	98.8	0.003	99.1	0.934
Stadiometer	97.1	0.434	97.4	0.008	99.4	0.059		0.302
NNC wooden board#	96.9		96.4		98.2		99.2	

#Reference equipment. *Significant at p-value <0.05 compared to reference equipment.

in height reading than reference Board in the mobile setting, but this is not significantly different in the stationary setting. In children 24-71 months of age in mobile setting, Allen's stick and Stadiometer mean differences in readings are not significantly different from reference equipment, but significantly different from the Aluminum-Acrylic Board. However, in a stationary setting, the mean difference in Aluminum-Acrylic Board readings are consistent with the reference height board. It is worth pointing out that before accuracy of equipment was evaluated, inconsistent readings and errors beyond acceptable limits obtained from inter- and intra-measurers reliability tests were excluded.

In Sta. Rosa municipality, the three test instruments used in the stationary setting produced a mean difference in height reading not significantly different from that of reference NNC Board, with Aluminum-Acrylic Board being the most accurate among the three instruments. However, when measuring children <1-23 months of age in a mobile setting, Allen's Stick gave mean difference in reading consistent with the reference instrument, but Stadiometer was better when measuring the children 24-71 months of age. All four equipment were consistent in height measurement in both settings, but Aluminum-Acrylic Board and Stadiometer was the most consistent for children <1-23 and

24-71 months of age, respectively.

In Bay municipality, consistency in length readings of children <1-23 months of age was noticeable in both mobile and stationary settings for all three equipment, except Stadiometer, when compared to the reference equipment. For children 24-71 months of age, measurements taken in mobile and stationary settings were not in agreement with those of reference instrument for Allen's Stick and Stadiometer.

DISCUSSION

CHNWs were able to measure height/length of children using all four different types of measuring equipment by following appropriate procedures in stationary and mobile settings, although some errors were made. Training, standardization, adherence to standard procedures, and monitoring of data quality must be regularly conducted to improve and maintain accuracy and reliability of measurements as shown in other studies (de Onis *et al*, 2004; Laar *et al*, 2018). Jamaiyah *et al* (2010) previously reported as long as the procedures are followed, all equipment in this study were reliable and valid for community-based assessment of children height/length.

Current programs activities involve end-users taking only single height/length measurements (NNC, 2012a), but asking end-users to take 2-3 measurements per child should be explored to ensure accuracy and minimal error. Other factors to be considered are diurnal variations; behavior and cooperation of the child being measured; accuracy and precision of instruments employed; training and experience of end-users; and data recording and interpretation (de Onis *et al*, 2004).

Measurers in the present study mainly had high school education and performed their tasks reliably subsequent to proper training of standardization protocols. Similarly, measurers in Ethiopia who are mostly farmers with little or no knowledge of anthropometry are able to provide reliable measurements after having undergone appropriate training (Ayele *et al*, 2012).

In summary, the present study shows the NNC Wooden Height Board can continue to serve as the standard equipment for measuring height/length of children in communities in stationary (at a suitable fixed location) and mobile (from house-to-house) settings despite its relatively high weight, but offsetted by its cheap manufacturing cost. Allen's Stick, Aluminum-Acrylic Board and Stadiometer are equivalent alternatives both in accuracy and reliability provided procedures recommended by the respective manufacturer are followed. A possible advantage, except for Aluminum-Acrylic Board, is their lighter weight. End-users experienced more difficulty in measuring height/length of younger children (<24 months of age, primarily due to the necessity of positioning the children in lying or recumbent position). According to the Centers for Disease Control (NHANES, 2007), placing infants and small children in a recumbent position often generates a sense of insecurity and consequently invokes a crying response. This reflects the need for additional training in handling younger children and for cooperation and assistance from parents/guardians in carrying out the measurement in (to a child) a stressful situation. Given the limited numbers of end-users in a given community, the issues raised should be addressed at local and national public health agencies if such surveys are to provide meaningful anthropomorphic data.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Arkansas Center for Health Improvement (ACHI). BMI screening program: height and weight measurement training manual. Little Rock: ACHI, 2018.

Ayele B, Aemere A, Gebre T, *et al*. Reliability of measurements performed by community-drawn anthropometrists from rural Ethiopia. *PLOS One* 2012; 7(1). doi: 10.1371/journal.pone.0030345

Berdanier C, Dwyer J, Heber D. Handbook of nutrition and food. 3rd ed. Boca Raton: CRC Press, 2013.

Briones R, Antonio E, Habito C, Porio E, Songco D. Strategic review of the food security and nutrition in the Philippines. Manila: Brain Trust, 2017. [Cited 2019 Oct 5]. Available from: https://docs.wfp.org/api/documents/WFP-0000015508/download/

de Onis MD, Branca F. Childhood stunting: a global perspective. *Matern Child Nutr* 2016; 12: 12-26.

de Onis MD, Onyango AW, Broeck JVD, Chumlea WC, Martorell R. Measurement and standardization protocols for anthropometry used in the construction of a new international growth reference. *Food Nutr Bulle* 2004; 25(Suppl): 527-36.

Department of Science and Technology-Food and Nutrition Research Institute [DOST-FNRI]. Philippine nutrition facts and figures 2015. Anthropometric Survey. Metro Manila: DOST-FNRI, 2016.

Diani H, Kapoor IOM. Indonesia accelerates fight against childhood stunting. Washington, DC: World Bank, 2018. [Cited 2019 Oct 8]. Available from: https://www.worldbank.org/en/news/feature/2018/06/26/indonesia-fights-stunting-commitment-convergence-and-communities

Gibson, RS. Principles of nutritional assessment. 2nd ed. New York: Oxford University Press, 2005.

Gordoncillo N, Talavera MT, Tandang N, Domingo DG. Technical report on the field trial of alternative height measuring equipment: Allenstick, aluminum-acrylic height board, stadiometer, and NNC wooden height board. Manila: National Nutrition Council, 2005.

Jamaiyah H, Geeta A, Safiza MN, *et al*. Reliability, technical error of measurements and validity of length and weight measurements for children under two years old in Malaysia. *Med J Malaysia* 2010; 65 Suppl A: 131-7.

Laar ME, Marquis GS, Lartey A, Gray-Donald, K. Reliability of length measurements collected by community nurses and health volunteers in rural growth monitoring and promotion services. *BMC Health Serv Res* 2018; 18: 118.

Mwangome MK, Fegan G, Mbunya R, Prentice AM, Berkley JA. Reliability and accuracy of anthropometry performed by community health workers among infants under 6 months in rural Kenya. *Trop Med Int Health* 2012; 17: 622-9.

National Health and Nutrition Examination Survey (NHANES). Anthropometry procedures manual. Manila: NHANES 2007. [Cited 2019 Oct 8]. Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf

National Nutrition Council (NNC). Implementing guidelines on Operation Timbang Plus (OPT+). Developed by the Inter-agency Technical Working Group on Child Growth Standards Approved for Nationwide Implementation by the NNC Governing

Board pursuant to NNC Governing Board Resolution No. 2, Series 2012a.

National Nutrition Council (NNC). Approving the guidelines on the fabrication verification and maintenance of wooden height boards. Governing Board Resolution No. 3, series of 2012b.

National Nutrition Council (NNC). Approving the guidelines on the selection of non-wood height and length measuring tool. NNC Governing Board Resolution No. 3, series of 2018.

Save the Children Cambodia. NOURISH Project introduced two community nutrition products. Pnom Penh: Save the Children Cambodia, 2015.[Cited 2019 Oct 9]. Available from: https://cambodia.savethechildren.net/news/save-children-nourish-project-introduced-two-community-nutrition-products.

Voss LD, Bailey BJ. Equipping the community to measure children's height: the reliability of portable instruments. *Arch Dis Childhood* 1994; 70: 469-71.

World Health Organization (WHO). Training course on child growth assessment: WHO child growth standards. Geneva: WHO, 2008.

World Health Organization (WHO). Nutrition Landscape Information System (NLIS) country profile indicators: interpretation guide. Geneva: WHO, 2010.