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Comparison of weighing scales for children ages 0 to 59 months in two municipalities in Laguna, Philippines

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ABSTRACT

Introduction: Accurate weight measurement is critical for assessing growth and nutritional status in children, yet errors due to equipment can affect reliability. This study evaluated reliability of weight measurements obtained by community health workers using four weighing tools: SECA model 878, NutriScale Digital, Tanita model HD-662, and mechanical hanging infant weighing scale. **Methods:** A cross-sectional study was conducted in two municipalities in Laguna, Philippines, where three pairs of end-users measured weight of 80 children aged 0-59 months in house-to-house and stationary setups across rural and urban areas. Inter- and intra-measurer reliability were assessed using correlation coefficients (CC), technical error of measurement (TEM), and coefficient of variation (CV). Benchmark values included TEM <0.1 kg and acceptable %TEM thresholds (≤1.5% intra-measurer; ≤2% inter-measurer). **Results:** All four tools demonstrated acceptable reliability. NutriScale and Tanita consistently recorded the lowest TEM and %TEM values across settings, followed by SECA, which also met acceptable standards. Variability in measurements, however, was observed between house-to-house and stationary setups, particularly in rural areas. Differences in tool performance appeared influenced not only by the device characteristics but also by contextual factors such as measurer consistency, child's age, and environmental conditions. **Conclusion:** Although NutriScale and Tanita showed higher consistency, measurement accuracy cannot be attributed to the scale alone. Field variability, proper calibration, and adequate measurer training remain critical for reliable assessments. Future research with larger samples and age stratification is recommended to better evaluate scale performance and inform tool selection for community-based programmes such as Operation Timbang (OPT).

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

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INTRODUCTION

Weight control across the population has been an important public health challenge (Sand *et al.*, 2014). In children, anthropometric measurements, including weight, reflect general health status, dietary adequacy, and growth and development over time (Fryar *et al.*, 2016). Being underweight, overweight, or obese in childhood and adolescence is associated with adverse health consequences throughout the life course (Lancet, 2017). A previous study in Malaysia found a significant difference between parental perceptions and children's actual weight, revealing that nearly half of parents misperceived their child's weight status (Zulaily *et al.*, 2020). Hence, accurate weight measurement is especially crucial for assessing the nutritional status of young children, as childhood weight status has long-term implications for health.

Globally, 45.4 million children under 5 years of age are wasted, while 38.9 million are overweight (Development Initiatives, 2021). In the Philippines, the 2018 Expanded National Nutrition Survey (DOST-FNRI, 2018) revealed that one in every five children (19.1%) under 5 years old is underweight and 5.6% are wasted, while the prevalence of overweight children has not changed from 2015 (3.9%) to 2018 (4.0%).

The American Academy of Pediatrics and the Child Health and Disability Prevention (CHDP) recognise that accurate serial anthropometric measurements can help identify underlying medical, nutritional, or social problems in children (California Department of Health Care Services, 2016, as stated in Casadei & Kiel, 2021). In addition, height and weight measurements routinely collected for child health records are potentially useful for clinical practice and research (Howe, Tilling & Lawlor, 2009).

In the Philippines, an annual weight- and height-taking activity is conducted through the National Nutrition Council's Operation Timbang Plus (OPT Plus). It is an important programme established in the 1970s for monitoring child growth and addressing malnutrition (FAO & NNC, 2017). Community nutrition and health workers (CNHWs), including Barangay Nutrition Scholars (BNS), use the programme to measure weight and height, enabling early detection of undernutrition and overnutrition and facilitating timely implementation of interventions like nutrition supplementation and dietary counselling.

The weighing scale is a critical tool in the success of OPT Plus, as it must provide accurate and consistent measurements while being durable enough for use in various settings. It is used in urban and rural areas across diverse contexts such as house-to-house visits and stationary setups in *barangay* (village) health centres. This means the weighing scale is frequently handled, transported, and exposed to varying weather conditions, requiring it to be both reliable and sturdy. While the National Nutrition Council (NNC) has relied on the Salter weighing scale for years, concerns have been raised about its cost and ease of use, highlighting the need for potential alternatives.

The NNC recognises the need to field-test other weighing scales, with a preference for lighter-weight, easy-to-use, and durable ones. Moreover, there is limited data on the reliability, technical error of measurement, and validity of weight measurement tools. In this regard, a field trial was undertaken to provide evidence on the accuracy, reliability, and ease of use of other commercially available weighing scales as possible alternatives to the currently NNC-approved mechanical hanging weighing scale for assessing the nutritional status of children under five. This study assessed the reliability of weight readings performed by several community health workers using four weight measuring tools, namely the SECA model 878, NutriScale Digital, Tanita model HD-662, and the Salter weighing scale. The performance readings of the three commercially available weighing scales were further compared against those obtained using the Salter weighing scale, which served as the reference in this study due to its widespread use in the Operation Timbang Plus programme in the Philippines.

METHODOLOGY

Study design and participants

A cross-sectional study was conducted in two municipalities in the province of Laguna, Philippines, representing rural and urban settings. Barangay Nutrition Scholars (BNS), Barangay Health Workers (BHW), and midwives, who routinely conduct child weighing, served as end-users. Three end-users pairs were designated in each *barangay*, with two measurers and one recorder. Children aged 0-59 months were selected from OPT lists. Using a 90% confidence level, a 10% margin of error, and a prevalence estimate of 0.19, the minimum sample sizes were 32 (rural) and 40 (urban). To ensure equal representation, a total sample of 80 children was used. Random selection was carried out while ensuring inclusion of both younger and older age groups.

Study sites

The two municipalities differed in terms of urbanity, population, income, and accessibility, based on the Philippine Statistics Authority-Philippine Standard Geographic Code (PSA-PSGC). One *barangay* per municipality was randomly selected for inclusion.

Weight measuring equipment

Four weighing devices were assessed: (1) Salter weighing scale, manufactured by Salter in England, United Kingdom; (2) SECA Model 878, manufactured by SECA GmbH & Co in Hamburg, Germany; (3) NutriDigital Scale, manufactured by Rice Lake Weighing Systems in Wisconsin, USA; and (4) Tanita Model HD-662, manufactured by Tanita Corporation in Tokyo, Japan. Detailed characteristics of each scale are provided in Table 1.

Three end-user pairs used all four devices to measure the same 40 children per site. Measurements followed UNICEF (1986) guidelines under two conditions: stationary and house-to-house setups. Children were brought to a central venue, where each measurer independently recorded two readings per child using colour-coded forms, which were submitted immediately to prevent recall bias. A research assistant monitored the procedures; a third reading was obtained if the difference between the two readings exceeded 0.5 g. After stationary weighing, the same children were visited at home for house-to-house measurements.

Data collection

End-users underwent training and standardisation to ensure consistent measurement techniques, correct equipment handling, and minimisation of user-related errors. All field activities adhered to COVID-19 safety protocols.

Data analysis

Descriptive statistics were used to summarise the characteristics of participants and end-users. Measurement consistency was examined through inter-measurer reliability using correlation coefficients, interpreted from slight to almost perfect agreement. Precision was evaluated using technical error of measurement (TEM), relative TEM, and coefficient of variation (CV),

Table 1. Summary of the physical description and fundamental designs of the four weight measuring equipment

Fundamental designs	*Salter scale*	*NutriScale digital*	*SECA 878 digital floor scale*	*Tanita digital bathroom scale HD-662*
1. Manufacturer	Salter	Rice Lake Weighing Systems	SECA GmbH & Co	Tanita Corporation
2. Manufacturer's Address/City	England, United Kingdom	Wisconsin, USA	Hamburg, Germany	Tokyo, Japan
3. Weight	0.8 kg	0.4kg	4kg	1.1kg
4. Dimension	150 mm dial size	Width: 90 Height: 25mm Length: 290mm	Width: 321mm; Height: 60mm; Depth: 360mm	Width: 290mm Height:30mm Depth: 295mm
5. Material	Metal body; Acrylic plastic glass for display; Stainless steel hooks	Stainless steel hook; Plastic body	Rubber platform; Glass display; Metal body	Glass display; Plastic body
6. Gradiation	0.1kg	0.01kg	0.01kg	0.1kg/0.2lb
7. Calibration				
a. Who (Agency) calibrates	DOST Region IV-A Metrology Division	DOST Region IV-A Metrology Division	DOST Region IV-A Metrology Division	DOST Region IV-A Metrology Division
b. How it was calibrated	Set of weights used	Set of weights used	Set of weights used	Set of weights used
c. When it was calibrated	July 2021	July 2021	July 2021	July 2021
d. Frequency of calibration	Before data collection and after every 10 measurements	Before data collection and after every 10 measurements	Before data collection and after every 10 measurements	Before data collection and after every 10 measurements
e. Fee for alibration	Php800 (USD 16)	Php800 (USD 16)	Php800 (USD 16)	Php800 (USD 16)

To be continued...

Table 1. Summary of the physical description and fundamental designs of the four weight measuring equipment (continued)

Fundamental designs	*Salter scale*	*NutriScale digital*	*SECA 878 digital floor scale*	*Tanita digital bathroom scale HD-662*
8. Maintenance				
a. Oiling	Not applicable	Not applicable	Not applicable	Not applicable
b. Cleaning	Alcohol sprayed on trouser	Alcohol sprayed on trouser	Clean the outside with a domestic cleaning agent or a commercially- available disinfectant (e.g., alcohol-based	Wiping with a damp cloth or alcohol-based wipe periodically
c. Corrosion	Refrain from using corrosive liquids or high-pressure washers	Refrain from using corrosive liquids or high-pressure washers	Refrain from using corrosive liquids or high-pressure washers	Refrain from using corrosive liquids or high-pressure washers
d. Care	Do not drop the scale or subject to violent shocks	Take out batteries when not in use. Use only the recommended battery type. Do not drop the scale or subject to violent shocks	Avoid stepping on the display. Use only the recommended battery type. Do not drop the scale or subject to violent shocks	Avoid stepping on the display. Use only the recommended battery type. Do not drop the scale or subject to violent shocks
e. Inspection of moving parts	With moving parts	With moving parts	Without moving parts	Without moving parts
6. Self-con tained parts	3 pcs (2 hooks, trouser)	5 pcs (hook, battery cover, 2 AA batteries, trouser)	7 pcs (6pcs batteries, battery cover)	3 pcs (2 AA batteries; battery cover)
a. The total number of batteries used	0	6	18	6
9. Storing	Store in a styro box when not in use.	Store in its pouch or box.	Store in its provided bag	Store in its box
10. Packaging	Styro box	Pouch and box	Bag	Box
11. Transporting	Easy to transport	Easy to transport	Difficult to transport	Easy to transport
12. Safety				

To be continued...

Table 1. Summary of the physical description and fundamental designs of the four weight measuring equipment (continued)

Fundamental designs	*Salter scale*	*NutriScale digital*	*SECA 878 digital floor scale*	*Tanita digital bathroom scale HD-662*
a. Stability	Depends on the structure where it is hanged	Depends on the structure where it is hanged	Stable	Stable
b. Presence/ absence of sharp edges or roughness	Has hooks	Has a hook	None	None
13. Durability				
a. Expected life	Not battery-operated but is prone to damage when setting up due to unstable hooks. Trouser used is not durable.	Battery-operated and is prone to damage when setting up due to unstable hooks. Trouser used is not durable.	Battery-operated, less prone to damage when setting-up	Battery-operated, less prone to damage when setting-up
b. Impact resistance	Not applicable	Not applicable	Not applicable	Not applicable
c. Functional parts	No buttons	Hold button; Power/ Zero buttons; units	2 in 1 key; start key; on-off switch	Weight mode switch
14. Portability				
a. Weight	Light	Light	Heavy	Light
b. Compactness	Not compact (with detachable parts)	Not compact (with detachable parts)	Compact	Compact
c. Ease of carrying	Easy but no provided bag	Easy	Heavy (bag for transport provided)	Manageable (no bag provided)
d. Ease of handling	Easy to handle	Easy to handle	Easy to handle	Easy to handle
15. Universality				
a. babies 0 to 6 months	Difficult for very young children	Difficult for very young children	Easy if a child is willing to be carried by the measurer	Easy if a child is willing to be carried by the measurer

To be continued...

Table 1. Summary of the physical description and fundamental designs of the four weight measuring equipment (continued)

Fundamental designs	*Salter scale*	*NutriScale digital*	*SECA 878 digital floor scale*	*Tanita digital bathroom scale HD-662*
b. infants 6 months to 2 years old	Difficult for young children	Difficult for young children	Easy to use for older children	Easy to use for older children
c. 3 to 5 years old	Trouser is too small for older children	Trouser is too small for older children	Easy to use on older children	Easy to use on older children
General				
16. Cost				
a. real cost	Approx. Php3,000 (USD 60)	Approx. Php640 (USD 72.80)	Approx. Php5,872 (USD 317.44	Approx. Php7,500 (USD 150)
b. cost of packing	Not applicable	Not applicable	Not applicable	Not applicable
17. Potential for a local	Present	Present	Present	Present
18. Instructions	Without a user's manual	With a user's manual	With a user's manual	With a user's manual

with acceptable thresholds of <1.5% for intra-measurer, <2% for inter-measurer, and CV% ≤5%.

The accuracy of each device was assessed by comparing mean weights with the Salter weighing scale (reference) using paired t-tests. Differences in user ratings across equipment were analysed using repeated-measures ANOVA, while Bland-Altman plots illustrated agreement between each device and the reference scale. Statistical analyses were performed using Stata version 12, developed by Stata Corp LLC in College Station, Texas, USA.

Adherence to ethical requirements

The study received ethics approval from the University of the East Ramon Magsaysay Memorial Medical Center Research Institute for Health Sciences (RIHS ERC Code: 0961/E/2021/046). Written informed consent was obtained from all end-users and from parents or guardians of participating children. All data and photo documentation were securely stored and treated as confidential.

RESULTS

Characteristics of children

A total of 80 children aged 0 to 59 months were recruited for the study. The youngest child was 5 months old and the oldest was 59 months old, both from the urban area. The mean age of the children was 30.6 ± 15.8 months. Among them, 34 (42%) were boys and 46 (57.5%) were girls. Based on age categorisation, 37 children (46.4%) were in the 0-23 months age group, while 43 children (53.7%) were in the 24-59 months age group. This distribution was similar across both urban and rural settings, with a slightly higher proportion of girls in both locations.

Inter-measurer reliability and accuracy

Table 2 presents the results of the inter-reliability analysis made across the measurers in different study areas. There was a high degree of reliability among measurers, as indicated by strong correlation coefficients based on recorded weights using the four types of weighing tools in both stationary and house-to-house settings. Errors of measurement were acceptable (all less than 2%) and the coefficients of variation (CVs) were below 5%, further supporting consistency among measurers. While the Salter scale was used as a reference tool to assess relative accuracy, it is acknowledged that these comparisons may primarily reflect inter-measurer reliability rather than absolute accuracy.

Moreover, the observed differences in weight readings made by two measurers utilising SECA and Tanita weighing scales in the stationary and house-to-house procedures were not significant, implying accuracy in the readings between these measurers. On the other hand, a significant mean difference was found when comparing measurer 1 with measurers 2 and 3 using the Salter tool in the stationary approach and between measurers 1 and 3 using the NutriScale in the house-to-house approach. In these comparisons, measurer 1 consistently provided a higher measurement. It was also evident that the lowest %TEM was registered using Tanita, seconded by NutriScale.

Similarly, weight readings by BNS in the urban area were reliable, as revealed in their almost perfect correlation coefficients. This was further shown in their small values of TEM, acceptable values of %TEM, and acceptable CV values. In addition, no significant differences were found in most pairwise mean comparisons made, except when measurer 1 was compared with measurers 2 and 3 using Salter in the house-to-house approach, where measurer 1 recorded significantly lower mean weights. Although all tools exhibited high inter-reliability under the house-to-house scheme, it was apparent that measurers exhibited a high degree of reliability (based on TEM) using Tanita.

Intra-measurer reliability and accuracy

Intra-measurer reliability was also performed to determine the degree of agreement between two repeated measurements performed by a single measurer. Absolute mean differences between the two weight measurements conducted by end-users in the rural area were not significant, except for measurer three using SECA in the stationary and house-to-house settings. Nevertheless, all measurers were reliable in their two measurements, as indicated by small TEMs and acceptable %TEM and CVs. The highest reliability was produced using the NutriScale. A high degree of intra-measurer reliability was observed, as specified in their correlation coefficients, with almost perfect agreement (Table 3).

Similarly, measurers from the urban area exhibited good reliability and consistency in their measurements. On average, there were no significant differences between the two measurements done by each measurer. Furthermore, intra-measurer reliability was observed among the measurers using the four weight measuring tools, as shown in the %TEM and CVs, which were all within acceptable values. Moreover, almost all correlation coefficients were equal to 1, implying a perfect agreement between the two measurements. The use of NutriScale provided the highest reliability, seconded by Tanita (Table 3).

Intra-measurer reliability assessment was further performed between house-to-house and stationary settings. There was a high degree of reliability between the two settings, as reflected in their correlation coefficients, both in the rural and urban areas, which were close to perfect. This indicated a strong correlation between the readings from the measurers in both settings. Small TEM values and acceptable values of %TEM and CVs also indicated consistency in the readings between house-to-house and stationary settings. However, statistical comparisons of mean weight readings between the two settings showed significant results, except for the Salter weighing scale, which was measured by those from the rural area of Laguna (Table 4).

Accuracy and consistency of other equipment

Considering the results of inter- and intra-measurer reliability, measurers with inconsistent measurements were excluded before testing the validity of the equipment. Table 3 presents the intra-measurer reliability and accuracy in weight measurements between house-to-house and stationary settings. Measurers using the Salter scale consistently recorded higher weight measurements compared to other scales, with the largest mean difference observed between SECA and Salter (0.11 kg), ranging from -0.05 kg to 0.27 kg. Statistical analysis confirmed that Salter produced significantly higher readings than SECA and Tanita. NutriScale closely matched Salter, with a mean difference of 0.03 kg, which was not statistically significant.

In the urban area, the mechanical hanging scale continued to record higher readings than SECA and Tanita in both stationary and house-to-house settings. NutriScale, however, showed agreement with the mechanical hanging scale across both setups. Percentages outside the limits of agreement ranged from 2.5% to 10%, with the highest discrepancies observed between Salter and SECA under stationary setups and between Salter and NutriScale in house-to-house setups.

NutriScale and Tanita exhibited the lowest TEM and %TEM values across both rural and urban settings, indicating relatively high precision. This observed consistency may reflect not only the performance of the weighing scales but also variations in measurers' techniques, environmental conditions, and context-specific factors. The Salter scale consistently recorded higher readings, while NutriScale closely matched its accuracy. Both setups

Table 2. Inter-measurer reliability and accuracy of three measurers in measuring the weight (kg) of children aged 0-59 months using different equipment in different setups and locations

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		1st Measurer	*SD*	*2nd Measurer*	SD					
STATIOARY -Rural Area										
Salter weighing scale	1 and 2	13.255	3.372	13.189	3.411	0.018*	0.999	0.127	0.959	4.049
	1 and 3	13.255	3.372	13.199	3.413	0.031*	0.999	0.118	0.891	4.048
	2 and 3	13.189	3.411	13.199	3.413	0.515	1.000	0.068	0.512	4.083
SECA	1 and 2	13.090	3.362	13.073	3.361	0.075	1.000	0.044	0.336	4.062
	1 and 3	13.090	3.362	13.089	3.361	0.925	1.000	0.058	0.446	4.063
	2 and 3	13.073	3.361	13.089	3.360	0.309	1.000	0.070	0.539	4.061
NutriScale	1 and 2	13.133	3.402	13.162	3.362	0.197	0.999	0.102	0.778	4.068
	1 and 3	13.133	3.402	13.131	3.383	0.913	1.000	0.050	0.384	4.085
	2 and 3	13.162	3.361	13.131	3.383	0.170	0.999	0.100	0.764	4.056
Tanita	1 and 2	13.130	3.381	13.105	3.371	0.170	0.999	0.081	0.618	4.072
	1 and 3	13.130	3.381	13.100	3.382	0.128	0.999	0.088	0.669	4.076
	2 and 3	13.105	3.371	13.100	3.382	0.639	1.000	0.047	0.357	4.074
HOUSE-TO-HOUSE - Rural Area										
Salter weighing scale	1 and 2	13.235	3.413	13.235	3.413	1.000	1.000	0.056	0.422	4.075
	1 and 3	13.235	3.413	13.220	3.401	0.154	1.000	0.047	0.354	4.071
	2 and 3	13.235	3.413	13.220	3.401	0.123	1.000	0.043	0.327	4.073
SECA	1 and 2	13.153	3.391	13.154	3.402	0.918	1.000	0.053	0.405	4.082
	1 and 3	13.153	3.391	13.173	3.412	0.136	1.000	0.060	0.453	4.085
	2 and 3	13.154	3.402	13.173	3.412	0.087	1.000	0.049	0.373	4.095

To be continued...

Table 2. Inter-measurer reliability and accuracy of three measurers in measuring the weight (kg) of children aged 0-59 months using different equipment in different setups and locations *(continued)*

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		1st Measurer	*SD*	*2nd Measurer*	SD					
NutriScale	1 and 2	13.198	3.390	13.204	3.401	0.743	1.000	0.070	0.532	4.071
	1 and 3	13.198	3.390	13.184	3.391	0.031*	1.000	0.030	0.228	4.072
	2 and 3	13.204	3.401	13.184	3.402	0.192	1.000	0.067	0.506	4.077
Tanita	1 and 2	13.156	3.403	13.163	3.403	0.638	1.000	0.061	0.461	4.088
	1 and 3	13.156	3.403	13.163	3.392	0.598	1.000	0.054	0.412	4.080
	2 and 3	13.163	3.402	13.163	3.392	1.000	1.000	0.030	0.225	4.078
STATIONARY-Urban Area										
Salter weighing scale	1 and 2	12.126	2.632	12.139	2.611	0.560	0.999	0.096	0.794	3.410
	1 and 3	12.126	2.632	12.140	2.640	0.431	0.999	0.077	0.633	3.434
	2 and 3	12.139	2.613	12.140	2.640	0.964	0.999	0.097	0.803	3.417
SECA	1 and 2	12.109	2.621	12.101	2.653	0.706	0.999	0.087	0.721	3.440
	1 and 3	12.109	2.621	12.104	2.642	0.685	1.000	0.054	0.448	3.430
	2 and 3	12.101	2.653	12.104	2.642	0.895	0.999	0.083	0.688	3.454
NutriScale	1 and 2	12.133	2.632	12.154	2.652	0.324	0.999	0.093	0.765	3.439
	1 and 3	12.133	2.632	12.152	2.651	0.205	0.999	0.067	0.555	3.438
	2 and 3	12.154	2.652	12.152	2.651	0.916	0.999	0.062	0.513	3.445
Tanita	1 and 2	12.114	2.621	12.119	2.642	0.664	1.000	0.051	0.418	3.431
	1 and 3	12.114	2.621	12.131	2.621	0.114	1.000	0.049	0.407	3.417
	2 and 3	12.119	2.64	12.131	2.621	0.303	1.000	0.054	0.442	3.430
HOUSE-TO-HOUSE-Urban Area										
Salter weighing scale	1 and 2	12.210	2.711	12.259	2.691	0.007*	0.999	0.083	0.682	3.486
	1 and 3	12.210	2.701	12.240	2.691	0.028*	1.000	0.062	0.505	3.487
	2 and 3	12.259	2.692	12.240	2.691	0.286	0.999	0.078	0.634	3.474

To be continued...

Table 2. Inter-measurer reliability and accuracy of three measurers in measuring the weight (kg) of children aged 0-59 months using different equipment in different setups and locations *(continued)*

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		1st Measurer	*SD*	*2nd Measurer*	SD					
SECA	1 and 2	12.190	2.691	12.175	2.691	0.177	1.000	0.049	0.405	3.487
	1 and 3	12.190	2.691	12.181	2.692	0.291	1.000	0.037	0.301	3.489
	2 and 3	12.175	2.691	12.181	2.692	0.585	1.000	0.050	0.413	3.493
NutriScale	1 and 2	12.215	2.690	12.229	2.692	0.470	0.999	0.085	0.698	3.475
	1 and 3	12.215	2.690	12.216	2.682	0.960	1.000	0.022	0.180	3.476
	2 and 3	12.229	2.691	12.216	2.682	0.456	0.999	0.081	0.665	3.475
Tanita	1 and 2	12.198	2.691	12.193	2.691	0.593	1.000	0.041	0.337	3.485
	1 and 3	12.198	2.691	12.195	2.690	0.772	1.000	0.038	0.311	3.486
	2 and 3	12.193	2.692	12.195	2.690	0.762	1.000	0.036	0.297	3.483

SD: Standard deviation; CC: Correlation coefficients; TEM: Technical error of measurement; CV: Coefficient of variation
[a]Using t-test for paired samples; *statistically significant at $p<0.05$

Table 3. Intra-measurer reliability and accuracy of three measurers (with two measurements) in measuring the weight of children aged 0-59 months using different equipment in different setups and locations

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		1st Measurement	*SD*	*2nd Measurement*	*SD*					
STATIONARY -Rural Area										
Salter weighing scale	1	13.255	3.370	13.255	3.361	1.000	1.000	0.027	0.207	4.015
	2	13.190	3.411	13.188	3.411	0.323	1.000	0.011	0.085	4.084
	3	13.203	3.402	13.195	3.420	0.323	1.000	0.034	0.254	4.082
SECA	1	13.093	3.371	13.088	3.361	0.660	1.000	0.050	0.382	4.064
	2	13.068	3.374	13.078	3.342	0.323	1.000	0.045	0.342	4.060
	3	13.100	3.361	13.078	3.341	0.037*	1.000	0.049	0.372	4.063
NutriScale	1	13.133	3.404	13.133	3.401	1.000	1.000	0.003	0.024	4.097
	2	13.162	3.361	13.163	3.361	0.372	1.000	0.007	0.056	4.039
	3	13.133	3.382	13.130	3.382	0.105	1.000	0.007	0.052	4.074
Tanita	1	13.140	3.401	13.120	3.371	0.461	0.999	0.119	0.909	4.076
	2	13.108	3.383	13.103	3.371	0.421	1.000	0.027	0.209	4.070
	3	13.098	3.381	13.103	3.371	0.323	1.000	0.022	0.171	4.078
HOUSE-TO-HOUSE -Rural Area										
Salter weighing scale	1	13.235	3.411	13.235	3.411	1.000	1.000	0.022	0.169	4.073
	2	13.235	3.412	13.235	3.412	-	1.000	0.000	0.000	4.078
	3	13.218	3.401	13.223	3.412	0.486	1.000	0.032	0.239	4.069
SECA	1	13.154	3.381	13.151	3.404	0.830	1.000	0.051	0.390	4.073
	2	13.158	3.392	13.150	3.423	0.520	1.000	0.051	0.390	4.092
	3	13.185	3.413	13.160	3.421	0.023*	1.000	0.050	0.380	4.098

To be continued...

Table 3. Intra-measurer reliability and accuracy of three measurers (with two measurements) in measuring the weight of children aged 0-59 months using different equipment in different setups and locations *(continued)*

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		1st Measurement	*SD*	*2nd Measurement*	*SD*					
NutriScale	1	13.200	3.390	13.197	3.401	0.291	1.000	0.015	0.111	4.066
	2	13.203	3.403	13.204	3.403	0.160	1.000	0.003	0.024	4.075
	3	13.184	3.401	13.184	3.401	0.897	1.000	0.008	0.064	4.078
Tanita	1	13.156	3.403	13.156	3.413	1.000	1.000	0.022	0.170	4.090
	2	13.163	3.401	13.163	3.411	1.000	1.000	0.027	0.208	4.086
	3	13.160	3.380	13.165	3.391	0.486	1.000	0.032	0.240	4.071
STATIONARY-Urban Area										
Salter weighing scale	1	12.125	2.631	12.128	2.630	0.323	1.000	0.022	0.183	3.407
	2	12.137	2.611	12.142	2.603	0.323	1.000	0.016	0.130	3.378
	3	12.138	2.642	12.143	2.643	0.323	1.000	0.016	0.130	3.426
SECA	1	12.105	2.621	12.113	2.612	0.446	1.000	0.043	0.358	3.416
	2	12.103	2.650	12.100	2.650	0.323	1.000	0.011	0.092	3.464
	3	12.103	2.643	12.105	2.641	0.743	1.000	0.034	0.277	3.444
NutriScale	1	12.132	2.632	12.134	2.633	0.323	1.000	0.007	0.055	3.432
	2	12.154	2.651	12.154	2.651	1.000	1.000	0.003	0.026	3.445
	3	12.152	2.651	12.153	2.651	0.323	1.000	0.004	0.037	3.444
Tanita	1	12.115	2.622	12.113	2.621	0.323	1.000	0.011	0.092	3.419
	2	12.118	2.641	12.120	2.640	0.323	1.000	0.011	0.092	3.444
	3	12.130	2.622	12.133	2.621	0.323	1.000	0.011	0.092	3.416

To be continued...

Table 3. Intra-measurer reliability and accuracy of three measurers (with two measurements) in measuring the weight of children aged 0-59 months using different equipment in different setups and locations *(continued)*

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		1st Measurement	*SD*	*2nd Measurement*	*SD*					
HOUSE-TO-HOUSE-Urban Area										
Salter weighing	1	12.210	2.700	12.210	2.700	1.000	1.000	0.016	0.129	3.499
	2	12.260	2.691	12.258	2.692	0.660	1.000	0.025	0.204	3.473
SECA	1	12.185	2.681	12.195	2.693	0.210	1.000	0.035	0.290	3.483
	2	12.170	2.681	12.180	2.692	0.103	1.000	0.027	0.225	3.492
	3	12.180	2.692	12.183	2.693	0.711	1.000	0.030	0.243	3.495
NutriScale	1	12.216	2.692	12.215	2.692	0.660	1.000	0.005	0.041	3.476
	2	12.227	2.692	12.232	2.694	0.078	1.000	0.014	0.114	3.475
	3	12.216	2.681	12.216	2.168	-	1.000	0.000	0.000	3.475
Tanita	1	12.195	2.690	12.200	2.692	0.323	1.000	0.022	0.183	3.488
	2	12.195	2.690	12.190	2.684	0.160	1.000	0.016	0.130	3.482
	3	12.198	2.690	12.193	2.693	0.160	1.000	0.016	0.130	3.484

SD: Standard deviation; CC: Correlation coefficients; TEM: Technical error of measurement; CV: Coefficient of variation[a]Using *t*-test for paired samples; - correlation and t cannot be computed because the standard error of difference is 0; *statistically significant at $p<0.05$

Table 4. Intra-measurer reliability and accuracy of three measurers (house-to-house vs. stationary) in measuring the weight of children aged 0-59 months in the rural area and urban area

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		House-to-House	*SD*	*Stationary*	*SD*					
Rural area										
Salter weighing scale	1	13.235	3.371	13.255	3.412	0.495	0.999	0.129	0.973	4.044
	2	13.235	3.412	13.189	3.411	0.056	0.999	0.109	0.822	4.081
	3	13.220	3.404	13.199	3.410	0.348	0.999	0.100	0.756	4.075
SECA	1	13.153	3.393	13.090	3.361	0.018*	0.999	0.120	0.914	4.068
	2	13.154	3.404	13.073	3.362	0.002*	0.999	0.125	0.952	4.076
	3	13.173	3.413	13.089	3.361	0.007*	0.999	0.142	1.081	4.080
NutriScale	1	13.198	3.394	13.133	3.402	0.012*	0.999	0.119	0.905	4.082
	2	13.204	3.404	13.162	3.363	0.237	0.999	0.154	1.171	4.057
	3	13.184	3.401	13.131	3.382	0.020*	0.999	0.103	0.780	4.076
Tanita	1	13.156	3.403	13.130	3.382	0.361	0.999	0.126	0.956	4.082
	2	13.163	3.401	13.105	3.374	0.021*	0.999	0.113	0.860	4.078
	3	13.163	3.394	13.100	3.384	0.011*	0.999	0.113	0.860	4.074
Urban area										
Salter weighing scale	1	12.210	2.704	12.126	2.623	0.004*	0.998	0.136	1.115	3.463
	2	12.259	2.691	12.139	2.601	0.001*	0.997	0.173	1.420	3.433
	3	12.240	2.690	12.140	2.641	0.001*	0.998	0.137	1.123	3.458
SECA	1	12.190	2.681	12.109	2.610	0.002*	0.999	0.121	0.992	3.450
	2	12.175	2.680	12.101	2.651	0.003*	0.999	0.115	0.945	3.478
	3	12.181	2.691	12.104	2.632	0.002*	0.999	0.119	0.979	3.469
NutriScale	1	12.215	2.684	12.133	2.632	<0.001*	0.999	0.104	0.851	3.454
	2	12.229	2.682	12.154	2.642	0.042*	0.996	0.168	1.378	3.460
	3	12.216	2.683	12.152	2.641	0.014*	0.998	0.118	0.972	3.460

To be continued...

Table 4. Intra-measurer reliability and accuracy of three measurers (house-to-house vs. stationary) in measuring the weight of children aged 0-59 months in the rural area and urban area (continued)

Equipment	*Measurer*	*Mean*				*p-value*[a]	*CC*	*TEM*	*% TEM*	*CV (%)*
		House-to-House	*SD*	*Stationary*	*SD*					
Tanita	1	12.198	2.692	12.114	2.623	<0.001*	0.999	0.113	0.930	3.453
	2	12.193	2.684	12.119	2.631	0.003*	0.999	0.114	0.937	3.463
	3	12.195	2.684	12.131	2.622	0.005*	0.999	0.105	0.861	3.450

SD: Standard deviation; CC: Correlation coefficients; TEM: Technical error of measurement; CV: Coefficient of variation
[a]Using *t*-test for paired samples; *statistically significant at $p<0.05$

yielded generally consistent results with minor variability, supporting the practical use of these tools for weight measurement in diverse field conditions. Nonetheless, the authors acknowledge that factors not controlled for in the study, such as the end users' experience and setting-related influences, may have contributed to measurement outcomes.

DISCUSSION

Weight has been routinely collected by community health and nutrition workers as part of Operation Timbang (NNC, 2012). There are several types of weighing scales: spring, hanging, beam balance, and digital. The Salter hanging weighing scale has been the recommended equipment for measuring the weight of children (WHO, 2002). The hanging scale is commonly preferred in many countries because it can be transported easily, can be used in almost any setting, and is relatively inexpensive (Valid International, 2018). Standardised measuring techniques recommended by WHO (2008) are followed. Recently, the National Nutrition Council (NNC) explored three other weighing scales that could be used in addition to the Salter hanging weighing scale.

The Salter scale has been widely used in the Philippines since the 1980s, particularly for mass weighing programmes like Operation Timbang (OPT) (Raneses, Manegdeg & Ramos, 1994). It has been recommended for field use alongside other tools, such as the infant beam scale and bar scale, with clinical scales suggested for use in health stations. Regular calibration and maintenance have been emphasised to ensure accuracy and reliability in growth monitoring (Raneses *et al.*, 1994). However, concerns about the durability of the Salter scale's spring mechanism have been highlighted in previous studies. Angood (2006) noted that the spring mechanism is prone to damage from overloading and frequent use, leading to permanent functional issues. These concerns are particularly significant in low-resource settings like the Philippines, where affordability, portability, and long-term reliability are critical for effective growth monitoring programmes.

The indices used to assess reliability in this study included the technical error of measurement (TEM), relative TEM (%TEM), coefficient of reliability (R), and intraclass correlation coefficient (ICC). NutriScale and Tanita emerged as the most reliable tools for weight measurement, demonstrating the lowest TEM and %TEM values in both rural and urban settings. The results demonstrated their precision and suitability for diverse field conditions. Similarly, a study by Jamaiyah *et al.* (2010) among Malaysian children under two years of age showed strong inter- and intra-examiner reliability for weight measurements, based on change in the mean and ICC. High reliability reduces the likelihood of measurement errors and ensures consistency across different users and locations.

This study found that the Salter weighing scale, which was used as the reference tool, consistently recorded significantly higher weight measurements compared to SECA, NutriScale, and Tanita in both stationary and house-to-house approaches, particularly in rural areas. In urban areas, the Salter scale also showed higher readings than SECA in both approaches and significantly higher readings than Tanita in the house-to-house approach. However, NutriScale demonstrated strong agreement with the Salter scale in both approaches. Despite being the reference tool, the Salter scale's tendency to record higher weight measurements compared to other tools (SECA, NutriScale, and Tanita) may result in overestimation of children's weight, consequently leading to inaccurate assessments of nutritional status, such as underestimating the prevalence of undernutrition or overnutrition.

NutriScale and Salter demonstrated reliability across both stationary and house-to-house settings, making them suitable for different operational contexts like large-scale surveys and household interventions. However, not all weighing scales were equally reliable; SECA and Tanita showed inconsistencies between settings. These findings are crucial for Operation Timbang (OPT) in the Philippines, where accurate and consistent weight measurements are essential for identifying underweight or overweight children and developing targeted nutrition programmes. Reliable weighing scales should be used to ensure data comparability across areas and for effective growth monitoring in both community health stations and household visits.

There were statistically significant differences observed in some readings among weighing scales (e.g., SECA, NutriScale, and Tanita compared to the Salter scale) and among measurers. However, these differences were within acceptable limits. This highlights the importance of proper training and regular calibration to minimise variability and ensure accurate measurements.

This study has several limitations that should be considered when interpreting the findings. Firstly, the sample size was relatively small, particularly for infants and among community nutrition and health workers across the various settings, which may limit generalisability. Secondly, the use of weighing scales in emergency settings was not assessed, despite their relevance in such situations. Previous work by Angood (2006) highlighted that hanging scales are often unsuitable for use in emergencies due to concerns around their accuracy and practicality. Thirdly, the observed variability in weight measurements is influenced not only by the performance of the weighing scales but also by differences in measurer reliability under varying conditions. Although a standardisation exercise was conducted at the start of the study to identify end-users at risk of inconsistent measurements, and training was provided to promote correct techniques, complete control over measurers' skill, environmental setting, and other contextual factors was not possible. Therefore, measurement reliability cannot be attributed solely to the weighing scales. Addressing these limitations in future research, particularly through larger sample sizes, inclusion of emergency-use contexts, and controlling of measurer and environmental variables, will allow for a more comprehensive and generalisable evaluation of weighing scales for young children.

CONCLUSION

This study showed that end-users, regardless of their initial training, were able to take reliable measurements after brief training. Intra- and inter-reliability analyses showed high degrees of reliability within and between the measurers, as shown in the computed correlation coefficients based on the recorded weight measured using the four weight-measuring tools, both in stationary and house-to-house settings.

All four weighing scales proved reliable, consistent results across rural and urban areas. However, significant differences were observed when comparing house-to-house and stationary setups. The Salter and NutriScale showed differences in the rural area, while the SECA and Salter scales had differences in both setups.

SECA, Tanita, and NutriScale are recommended as reliable alternatives to the Salter weighing scale for measuring the weight of children aged 0 to 59 months. Ensuring accurate results requires proper calibration, initial training, and regular recalibration, particularly in community-based programmes like Operation Timbang (OPT).

Disclaimer

This study was conducted for comparative evaluation and research purposes, without funding, sponsorship, or endorsement from any of the weighing scale brands mentioned. The authors have no affiliations or financial ties with any of the evaluated brands. The findings were based on objective assessments and do not endorse any specific brand.

Local government and other entities are encouraged to make procurement decisions based on their needs and the National Nutrition Council guidelines. The results aimed to support evidence-based decision-making and should not be seen as mandatory directives.

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Authors' contributions

Domingo DGC, principal investigator, conceptualised and designed the study, prepared the draft of the manuscript, and reviewed the manuscript; Talavera MTM, led the training of end-users and standardisation on the acceptability of weighing scales and reviewed the manuscript, Bustos AR co-led the data collection in the rural community and reviewed the manuscript; Tandang NA, co-led the data collection in the rural community, conducted the study, data analysis and interpretation, assisted in the drafting of the manuscript; Africa LS, led the data collection in the urban community and reviewed the manuscript; Salunga DG assisted in objective setting, drafting and reviewed the manuscript, Abella ERF assisted in the drafting of the manuscript, reviewed the manuscript

Conflict of interest

The authors declare no conflict of interest.

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