Mal J Nutr 19(3): 303 - 309, 2013

# Reliability and Validity Test of Digital Infant Length Measurement Board with Sonar Sensor Precision

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## ABSTRACT

**Introduction**: The most prevalent malnutrition problem in Indonesia among young children is low height for age. Height or length of the young is known to be difficult to measure. This study was aimed at developing an instrument called *Pengukur Panjang Badan Bayi Digital* (P2B2D) Version 1.0 based on the main consideration of WHO recommendations on accuracy and precision of length measurements. **Methods**: Design of the study included instrument development, and reliability and validity tests on the instrument. This study involved 53 children aged below 2 years measured by three examiners using three different instruments namely, the P2B2D, wood length-board, and mica length-board. **Results**: The reliability coefficients of the P2B2D ranged from 0.747 (inter-method reliability against mica length-board using TEM analysis) to 0.966 (inter-method reliability against wood length-board using Pearson correlation analysis). The corresponding validity coefficients were 0.864 and 0.963, respectively. The only problem that emerged with the P2B2D was its weight, which was relatively heavy (6 kg). **Conclusion**: The reliability and validity of the P2B2D could be considered as substantial to excellent. It is recommended that this instrument be improved by minimising possible source of error and experimenting with different types of sensors.

**Key words:** Child length measurement, sonar sensor

## INTRODUCTION

The main method in nutritional status assessment is anthropometry, which measures human body size and dimension. There are three most popular indices in anthropometry measurements, namely weight for age (WFA), height for age (HFA) and weight for height (WFH). In Indonesia, data shows that the most prevalent malnutrition problem is related to low height for age index (stunting). Height (measured vertically) or especially length (measured horizontally) is known to be more difficult to measure than weight. The digital weight scale is available and weight measurements could be conducted relatively reliably and accurately. However, length measurement is usually conducted using an instrument that is not very accurate and rather conventional. Parallax error is common and even the most skilful anthropometrist should apply extra caution when length is to be measured in a reliable and valid way. The regular length-board is both bulky and impractical to be used comfortably in the field. So far no digital-precision length measurement tool is

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available despite its high importance and demand. Therefore, there is a need to develop an instrument to measure length more accurately and precisely to minimise measurement error.

WHO (2006) has set conditions so as to maintain accuracy and precision in length measurement. First, the instrument should be placed on a flat base. Second, the subject lies in a supine position on a recumbent length table or measuring board. The crown of the head must touch the stationary, vertical headboard. The subject's head is held with the line of vision aligned perpendicular to the plane of the measuring surface. Third, the shoulders and buttocks must be flat against the table top, with the shoulders and hips aligned at right angles to the long axis of the body. The legs must be extended at the hips and knees and lie flat against the tabletop with the arms resting against the sides of the trunk. The person measuring must ensure that the legs remain flat on the table and must shift the movable board against the heels. Care has to be taken to extend the infant legs gently. Fourth, the length is recorded to the nearest 0.1 cm.

Considering the above conditions, Syafiq & Prasetya (2011) have designed a prototype of a digital length measurement tool employing a sonar sensor to detect if the crown of the head, calf, and heel have been positioned properly. The sensors will activate LED light on the digital display panel of the instrument when touched. Thus, the measurement could only be made (by pushing a button) after all of those three LED lights are on. The instrument is called *Pengukur Panjang Badan Bayi Digital* (digital infant length measurer/P2B2D) Version 1.0.

This study aimed at developing P2B2D Version 1.0 based on the considerations of the WHO recommendations in relation to accuracy and precision of length measurement; other considerations informally addressed included portability by using light weight materials and a foldable board structure; and infant comfort during measurement by using soft baby-friendly materials and non-intimidating design elements.

## METHODS

The design of the study included instrument development, and reliability and validity tests on the instrument. Instrument development was based on prototype designed by Syafiq & Prasetya (2011). Reliability tests included intra-method and inter-method reliability test (Armstrong, White & Saracci, 1994;Trochim, 2002). The intra-method reliability test was conducted through inter-examiner reliability test which involved three examiners. Inter-method reliability was tested by comparing measurement results of P2B2D Version 1.0 to the results of other instruments' (wood and mica lengthboards) measurement. Then the correlation coefficient (Pearson) was calculated to produce reliability coefficient (Armstrong *et al.*, 1994). Validity coefficient was derived from the reliability coefficient under the assumptions of the parallel test model (Armstrong *et al.*, 1994). Assumptions made included: first, measurement error is not correlated to the true value; second, first and second measurement errors have similar variances and precision (especially applied to intra-method reliability test); third, there is no correlations between both the measurement errors. Within this model, validity coefficient could be derived from reliability coefficient as its square root value.

This study involved 53 children aged below two years who were measured by three examiners (A, B, and C with A being considered as the most expert measurer) using three different length measuring instruments namely P2B2D Version 1.0, wood length-board, and mica length-board. The wood length-board is a common device for length measurement and is made of wood with a fixed headboard and movable footboard, using plastic measuring tape alongside the board. The mica length-board is a simpler, less bulky length-board, using plastic mica as the main material; hence it is much lighter than the wood length-board, but uses a similar plastic measuring tape to read the measurement. Thus, both length-boards rely on the human eye to measure the length aided by the plastic measuring tape. All three examiners were graduates of the Department of Nutrition, Faculty of Public Health University of Indonesia and they were specially trained to use and to refresh their measuring skills for purposes of this study. Each respondent was measured by three examiners using three instruments. In each measurement, one child was measured twice (duplo). Three children was measured in one work-day. A rotation system was used to ensure minimum fatigue of the child and measurer; further it would help maintain each measurement as exclusive and un-correlated to each other. Instrument development took three months while reliability and validity tests were completed in a month. The study was conducted from March-October 2012.

Analyses were conducted to produce reliability and validity coefficients using Pearson correlation analysis for both intra- and inter-method tests. Analysis on anthropometric measurements were subjected to standardisation analysis to measure examiner's precision and accuracy (WHO, 1983). Additional analysis was also carried out to measure error variability or error margin in anthropometry by calculating accuracy index called Technical Error of Measurement (TEM) as explained in WHO Multicentre Growth Reference Study Group (WHO MGRS, 2006) and in Jamaiyah *et al.* (2010).

## RESULTS

The instrument was developed based on the prototype designed by Syafiq & Prasetya (2011) as shown in Figure 1. Compliance to WHO recommendations on accuracy and precision of length measurement was the main consideration in designing the tool; the portability consideration was taken care of

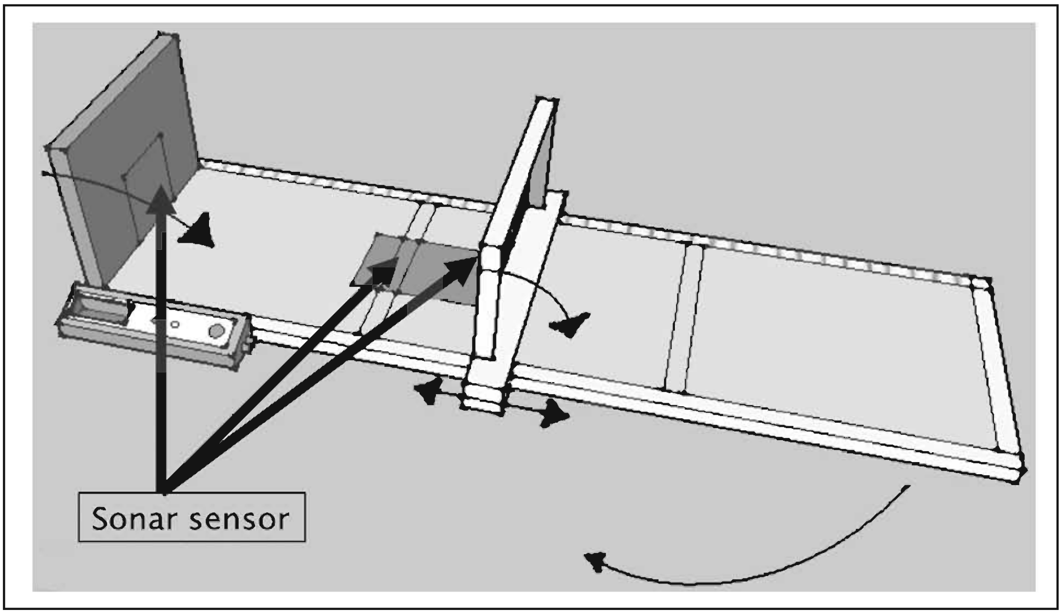


**Figure 1.** Prototype of P2B2D Version 1.0

by using light weight materials and foldable board while comfort was considered by using baby-friendly soft materials and non-intimidating design elements. To assist the measurement, three sonar sensors were applied to detect if crown of the head, calf, and heel had been positioned properly. The sensors activated the LED lights on the digital display panel of the instrument when touched. Thus, measurements could only be made (by pushing a button) after all of those three led lights went on.

Figure 2 shows the P2B2D Version 1.0 that was used to measure infant length in a laboratory setting.

WHO standardisation procedures on anthropometric measurement analysis (Table 1) shows that examiner A who was considered as the most expert had indeed the best precision as expected (lowest $\Sigma d^2$). Examiner B had the lowest precision (largest $\Sigma d^2$) and examiner C had the lowest accuracy (largest $\Sigma D^2$). The sign test for both accuracy and precision indicated no systematic bias for all examiners.

Pearson correlation analyses show that intra- and inter-method reliability coefficients were very high and indicated excellent agreement between measurements. Consequently, under the parallel test model,

**Figure 2.** Using P2B2D Version 1.0 in laboratory setting

**Table 1.** Standardisation analysis based on WHO (1983)

| *Examiner* | $\Sigma d^2$ | *Sign* | $\Sigma D^2$ | *Sign* |
|---|---|---|---|---|
| A | 178.20 | 26/50 | - | - |
| B | 321.11 | 28/49 | 915.51 | 25/52 |
| C | 210.52 | 26/49 | 996.94 | 27/52 |

$\Sigma d^2$= precision measure $\Sigma D^2$= accuracy measure the validity coefficients were equivalent. Table 2 shows the results of Pearson correlation.

Further analysis employing TEM measurements based on TEM and percent TEM values for intra-examiner test, consistent with the WHO standardisation results, examiner A was found to have the lowest error (hence, most accurate) while examiner B had the largest error (hence, least accurate). Reliability coefficients and validity coefficients for examiners A, B, and C were almost similar with examiner B having the lowest coefficients. However, the inter-examiner reliability and validity coefficient showed that examiner A compared to examiner C had the lowest reliability and validity coefficient, that is 0.887 and 0.942, respectively (A against B: 0.906 reliability coefficient and 0.952 validity coefficient; B against C: 0.902 reliability coefficient and 0.950 validity coefficient). Interestingly, TEM analysis revealed different results on reliability and validity coefficients of P2B2D Version 1.0 compared to direct measurement of Pearson correlation coefficients.

Under TEM analysis, reliability and validity coefficients of the newly developed instrument were 0.749 (reliability coefficient) and 0.865 (validity coefficient) against wood length-board and 0.747 (reliability coefficient) and 0.864 (validity coefficient) against mica length-board. These results indicate only substantial agreement (between 0.6-0.8 coefficient values) between measurement results of new and old instruments. However, coefficient for wood length-board against mica showed excellent agreement (coefficient value >0.8) with reliability coefficient of 0.999 and validity coefficient of 0.999. Table 3 shows coefficients based on TEM analyses.

## DISCUSSION

The manufacture of P2B2D Version 1.0 was done in a home-based workshop and assembling was done manually. These factors limit the *finesse* of the product; moreover, it lacked machine-made precision. However, the tool was considered as applicable as it endured field testing as well as reliability and validity testing. The only problem experienced during field testing was the weight of P2B2D Version 1.0 which was relatively heavy (6 kg, compared to mica lengthboard's 3 kg and wood lengthboard's 5 kg). The main contributor to this weight was the use of a steel frame in the base structure of P2B2D Version 1.0. In future, the plan is to use only light materials with adequate strength and resistance to physical changes due to temperature and humidity fluctuation.

Problems related to design found in field testing were (i) the need to position various components including sensor tower and measurement display device that were not

**Table 2.** Reliability and validity coefficients based on Pearson correlation

| *Reliability/validity type* | *Reliability coefficient* | *Validity coefficient* |
|---|---|---|
| *Intra-method P2B2D (inter-examiner)* | | |
| Examiner A-B | 0.955 | 0.977 |
| Examiner A-C | 0.950 | 0.975 |
| Examiner B-C | 0.955 | 0.977 |
| *Inter-method* | | |
| P2B2D-Lengthboard wood | 0.966 | 0.983 |
| P2B2D-Lengthboard mica | 0.959 | 0.979 |
| Lengthboard wood-mica | 0.997 | 0.998 |

Reliability coefficient measured using Pearson correlation test; Validity coefficient = √ reliability coefficient

**Table 3.** Reliability and validity coefficients based on TEM analyses

| *Reliability type* | *TEM* | *%TEM* | *Reliability coefficient* | *Validity coefficient** |
|---|---|---|---|---|
| *Intra-examiner* | | | | |
| Examiner A | 1.68151 | 2.35034 | 0.938 | 0.969 |
| Examiner B | 3.02934 | 4.23533 | 0.816 | 0.903 |
| Examiner C | 1.98604 | 2.77182 | 0.960 | 0.980 |
| *Inter-examiner* | | | | |
| Examiner A-B | 2.16356 | 3.02245 | 0.906 | 0.952 |
| Examiner A-C | 2.35514 | 3.28939 | 0.887 | 0.942 |
| Examiner B-C | 2.19479 | 3.06581 | 0.902 | 0.950 |
| *Inter-method* | | | | |
| P2B2D-Lengthboard mica | 3.66660 | 5.06002 | 0.747 | 0.864 |
| P2B2D-Lengthboard wood | 3.63443 | 5.00904 | 0.749 | 0.865 |
| Lengthboard mica-wood | 0.17594 | 0.23959 | 0.999 | 0.999 |

$TEM=\Sigma D^2/2N$; $\%TEM=(TEM/\bar{X})*100$; Reliability coefficient=$1-\{(TEM)^2/SD^2\}$; Validity coefficient = $\sqrt{\text{reliability coefficient}}$

distracted by infant's movements; (ii) ensure flatness of lengthboard bed is further aligned smoothly; and (iii) to have the sonar sensor at the head wrapped in a less protruding way so as not to hurt the infant's head.

According to WHO MGRS (2006), the measurement results of examiners B and C could be considered as acceptable since their TEM values were within + 2 times of expert's TEM value (examiner A). However, Norton & Olds (2000) in Jamaiyah *et al.* (2010) using beginner anthropometrist cut-off values (<2.0% for length) state that the values obtained by all examiners were not acceptable considering that their percent TEM values were all more than 2.0%. These results indicate that performance of the three examiners was similar and would not affect instrument assessment results.

Results of TEM analyses might reflect different characteristics of P2B2D Version 1.0 compared to those of other conventional length-boards. The reading of measurements in P2B2D Version 1.0 was done digitally using sonar sensor while in conventional length-boards, the human measurer does the reading. This poses a different source of error, which is human parallax error related to the position of eyes during reading in conventional length-boards measurement and the possibility of decreasing accuracy due to Doppler Effect in sonar-sensing distance measurement in P2B2D Version 1.0. The wood and mica length-boards, however, shared a similar source of error in this case, and this might explain their excellent agreement in measurement results.

Beside difference in visual measuring devices, both P2B2D Version 1.0 and conventional length-boards faced a similar problem of infant length measurement. It is well known that length measurement is more difficult to be performed flawlessly compared to other anthropometric measurements due to difficulty in ensuring that the subject is maximally stretched out for the measurement and a distressing measurement environment as examiners often have to repeat measurements on crying and struggling infants (WHO MGRS, 2006). Correspondingly, Jamaiyah *et al.* (2010) report lower reliability and accuracy coefficients of length measurement compared to weight measurement.

Despite the need for improvements to the design and architectural aspect of the instrument, this study has successfully developed a sonar-sensing infant length measurement device (P2B2D Version 1.0) that was tested for reliability and validity. The reliability coefficients of P2B2D Version 1.0 calculated by different methods ranged from 0.747 (inter-method reliability against mica length-board using TEM analysis) to 0.966 (inter-method reliability against wood length-board using Pearson correlation analysis). The corresponding validity coefficients were 0.864 and 0.963, respectively. These coefficients indicate that the reliability and validity of P2B2D Version 1.0 could be considered as substantial to excellent. It is recommended that this instrument be improved by minimising possible sources of error related to decreasing accuracy due to Doppler Effect. Perhaps, there is a need to experiment with different types of sensors, for example laser-based.

## ACKNOWLEDGEMENTS

This study was funded by University of Indonesia Research Grant No 1599/ H2.R12/HKP.05.00/2012

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