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Validity assessment of a portable anthropometer to measure length in 24-month children from the 2015 Pelotas Birth Cohort

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Abstract

Objective: This study aimed to assess the validity of a portable anthropometer against the gold standard among 2-year-old infants from the 2015 Pelotas (Brazil) Birth Cohort.

Design: Birth cohort study.

Setting: A fixed Harpenden® infant anthropometer was considered as the gold standard for measuring infant length due to its greater precision and stability. The portable SANNY® (model ES2000) anthropometer was the instrument to be validated. The acceptable mean difference in length between the anthropometers was 0·5 cm. In order to compare length estimates, the interviewers carried out two length measures for each of the anthropometers (fixed and portable) and for each child. The mean of the two lengths was calculated for each anthropometer, and their difference was calculated.

Participants: A subsample of 252 24-month-old members of the 2015 Pelotas (Brazil) birth cohort study.

Results: Children's mean age was 23·5 months. According to Bland–Altman plot, there were no differences in overall lengths between the portable and the fixed anthropometers, or in lengths according to sex. There was a high overall concordance between the length estimates of the fixed and portable anthropometers ($\rho = 0{\cdot}94$; 95 % CI 0·92, 0·95).

Conclusions: The portable anthropometer proved to be accurate to measure the length of 24-month-old infants, being applicable to studies using the same standardised protocol used in the present study.

Keywords
Validity
Anthropometer
Children
Length
Cohort

Measuring infants' length is an important practice initiated soon after birth and continued throughout childhood as a tool for clinical and public health surveillance. In order to globally standardise the length measurements, the WHO Multicentre Growth Reference Study developed the WHO Child Growth Standards, based on length/height, weight and age[1]. The curves, used in over 100 countries, describe how children should grow when free of disease and raised following healthy practices, such as adequate breast-feeding and a non-smoking environment from birth to 3 years of age[2]. For instance, children with length below 2 SD from the length-for-age curve or with weight above 2 SD from the weight-for-length curve, respectively, present evidence of stunting and overweight[3].

In this sense, the length measurement is widely applied as a child development indicator, being also used to detect intra-uterine growth restrictions, inadequate postnatal feeding and chronic malnutrition[4]. Hence, performing accurate anthropometric measurements is imperative to assess nutritional status and growth of infants and toddlers[5].

The gold standard equipment to measure length among children younger than 24 months of age is the anthropometer, which measures recumbent length (lying down) on a board made of wood or other sturdy material. The anthropometer is composed of a movable piece that serves as footboard and a fixed part serving as headboard. The instrument should be placed on a flat and stable surface, such as a table. Unless there is a digital counter, a

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measuring tape should be fixed along the length of the board[6]. This method is widely applied and suitable for clinical evaluations.

For population-based studies that conduct household assessments of children's length, an adequate environment for an accurate measurement is not always feasible. Additionally, the increased size and weight of the anthropometer may be difficult for the transportation of the device by interviewers. One option would be the adoption of portable devices that could be more easily transported.

Although portable devices would facilitate the logistics during field work, it is necessary to ensure that these are accurate devices to measure children's length, since errors on the measurements could lead to misdiagnosis of overweight and underweight[5]. This study was conducted with a subsample of 24-month-old children, members of the 2015 Pelotas (Brazil) birth cohort, who attended to the research clinic during the regular birth cohort follow-up that occurred during 2017. The aim of this study was to assess the validity of a portable anthropometer compared with the gold standard in 24-month-old infants.

Methods

The present study was carried out in a subsample of the 2015 Pelotas (Brazil) birth cohort. This birth cohort includes all children who were born alive in the five maternity wards of Pelotas (Brazil) between 1 January and 31 December 2015, and whose mothers resided in the urban area of the municipality (n 4275). Participants were interviewed during perinatal study and followed-up when aged 3, 12 and 24 months. More details about the birth cohort can be obtained elsewhere[7].

During the 24-month follow-up of the 2015 Pelotas birth cohort – that occurred during 2017, all children and mothers recruited during the perinatal study were invited to attend to a research clinic at the Federal University of Pelotas, Brazil. The mothers were interviewed, and the children were measured by trained personnel. Interviewers informed mothers that two length measures would be performed in different anthropometers (fixed and portable) in order to compare length estimates. The extra length measurements using the portable anthropometer did not modify or interfere on the logistics of interviews.

A fixed Harpenden® infant anthropometer, with amplitude between 30·0 and 110·0 cm and 0·1 cm accuracy, was considered as the gold standard for the measurement of infant's length due to its greater precision and stability. The portable SANNY® (model ES2000) anthropometer, with amplitude between 20·0 and 105·0 cm and 0·5 cm accuracy, was the instrument to be validated.

To estimate the necessary sample size for our study, we considered Willett's proposal of using between 100 and 210 individuals for validation studies[8]. Still, a sample size calculation was performed assuming an acceptable average length difference between the anthropometers equal to 0·5 cm. We accepted this level of difference as the precision of the portable anthropometer is also 0·5 cm. The estimated sample size required 250 children, who were randomly selected from the children who attended to the research clinic during the 2017 birth cohort follow-up. Data collection occurred between August and September, in Pelotas, Brazil.

Previously to data collection, interviewers and researchers who acted as anthropometrists were trained to carry out length measurements in children of the same age range. A gold standard anthropometrist also participated in the training, being possible to measure the inter-anthropometrist accuracy by comparing length measurements taken by anthropometrists and the gold standard anthropometrist; and intra-anthropometrist reliability by comparing the first and second length measures taken by the same anthropometrist. Four trained researchers performed the length measurements in the portable anthropometer at the research clinic, whereas the measurements on the fixed anthropometer were performed by trained interviewers from the 2015 Pelotas Birth cohort.

The length measurements of both anthropometers followed the given protocol: (a) ask the mother to remove children's shoes and socks, as well as bulky clothing, particularly diapers and head adorners; (b) the available anthropometers are placed on a flat and firm table; (c) a disposable paper towel is placed over the anthropometers' platform to prevent the child from being in direct contact with its surface; (d) the interviewer requests the mother to lay the child on her/his back, over the anthropometer, and to remain close to the child's head to calm him/her down during the measurement, if necessary; (e) during the measurement, the interviewer places a hand on the child's knee, to force it lightly against the apparatus and, with the other hand, move the mobile platform until it reaches the sole of the feet. The child's feet should be alongside the platform, and the head should stand against the anthropometer's fixed platform. If the child is agitated, it is necessary to gently force the knees and ankles down and simultaneously push the mobile platform against child's feet sole; (f) right after the measurement, the interviewer should discard the paper towel, preferably in front of the mother, and sanitise the equipment with alcohol gel. First, the interviewers did the measurements using the fixed infant anthropometer. Second, a researcher responsible for the study was called to measure the length using the portable infant anthropometer. Thus, researchers had no access to the length information measured by the interviewers. Children who presented any health or physical problem that could interfere on the measurements were not included in the study (n 1).

Parametric tests were used because the length of the sample showed a symmetric distribution. Prevalence and 95 % CI were used to describe the sample according to categorical variables, while mean and standard deviations

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were used for continuous variables. The sample was described according to children's and mothers'/families' characteristics. Children variables were sex (female and male), z-scores of height- and weight-for-age (≤ -2, $-2 < z < 2$, ≥ 2)[9,10] and the mean age (in months) at the moment the measurements were taken. The characteristics of the mothers were schooling in years of study (0–4, 5–8, 9–11 and ≥12), self-reported skin colour (black, brown, white and other) and mean age (in years) at the moment the measurements were taken. The monthly family income in minimum wages (≤1, 2–3, 4–6, 7–9 and ≥10) was the only family characteristic considered.

The mean length was calculated considering the first and second length measures of both portable and fixed anthropometers, then compared using paired Student's *t* test. The Bland–Altman method was used to characterise the concordance between the length measurements of both anthropometers. The Lin's Concordance Correlation Coefficient (ρ_C) was also calculated to analyse the overall concordance, and the concordance according to sex. All analyses were performed using Stata 15.0 software (Stata Corp.).

Results

The sample included 252 children. Children's, mothers' and families' sociodemographic characteristics are described in Table 1. The mean age of analysed children was 23·5 (SD = 0·6) months, while the mean age of their mothers was 29·3 (SD = 6·3) years. The majority of the children had mothers who completed from 9 to 11 years of study, had white skin colour and were part of a family earning from two to three minimum wages per month. Children from our sample were on average lower compared with the general 2015 Pelotas birth cohort population, which was used as reference population (mean sample height = 86·4 (SD = 3·4) *v.* mean cohort height = 86·7 (SD = 3·6)).

The mean length of the portable and the fixed anthropometers is described in Table 2. The mean of the differences ranged between 0·2 and 0·3, while the error variance ranged from 1·2 to 1·8 cm. There were no statistically significant differences between the estimates of the fixed and portable anthropometers.

In Fig. 1, Bland–Altman's plot shows a mean length difference of 0·2 cm (95 % CI 0·1, 0·4) between the fixed and portable anthropometers, with limits of agreement ranging from −2·2 to 2·6 cm. The pattern of spread of the observations in the graph reveals a high concordance between the length estimates of the fixed and portable anthropometers. Similar results were obtained after analysing according to sex. The mean length difference for boys was 0·2 cm (95 % CI 0·0, 0·5; limits of agreement: −2·4, 2·9), while for girls was 0·2 cm (95 % CI 0·0, 0·39; limits of agreement: −2·0, 2·4) (Fig. 2).

Table 1 Sociodemographic characteristics of the participants included in the study and the total cohort (Pelotas, Brazil; *N* 252)

	Validation study		2015 Pelotas cohort		
Variables	*N*	%	*N*	%	*P*-value*
Sex					0·218
Female	114	45·2	2111	49·4	
Male	138	54·8	2164	50·6	
Height-for-age (z-score)†					0·342
$z \leq -2$	10	4·0	135	3·5	
$-2 < z < 2$	234	94·0	3599	92·8	
$z \geq 2$	5	2·0	145	3·7	
Family income (minimum wages)†					0·337
≤1	43	17·2	560	14·2	
2–3	127	50·8	1952	49·4	
4–6	49	19·6	899	22·8	
7–9	17	6·8	229	5·8	
≥10	14	5·6	308	7·8	
Mother's schooling (years)					0·839
0–4	20	7·9	391	9·2	
5–8	65	25·8	1095	25·6	
9–11	92	36·5	1458	34·1	
≥12	75	29·8	1330	31·1	
Mother's skin colour					0·458
Black	44	17·5	667	15·6	
Brown	39	15·5	551	12·9	
White	168	66·6	3024	70·9	
Other	1	0·4	26	0·6	
	Mean	SD	Mean	SD	*P*-value‡
Age (months)	23·5	0·6	24·3	0·7	<0·001
Mother's age (years)	29·3	6·3	29·7	6·6	0·423

*Fisher's exact test comparing sociodemographic variables between the validation study sample and the 2015 Pelotas cohort.
†Totals might not sum 252 due to missing information.
‡Paired student's *t* test to test difference by means.

Table 2 Overall mean length in centimetres measured by the fixed and the portable anthropometers, and according to sex. The mean of the differences of the portable anthropometer subtracted by the fixed anthropometer is also shown (Pelotas, Brazil; *N* 252)

	Fixed anthropometer		Portable anthropometer		Mean of the differences (σ^2)		*P*-value*
	Mean	SD	Mean	SD			
Overall	86·4	3·4	86·6	3·5	−0·2	1·5	0·493
Sex							
Female	85·8	3·4	86·0	3·5	−0·2	1·2	0·680
Male	86·9	3·4	87·2	3·5	−0·3	1·8	0·575

σ^2, variance.
*Student's *t* test between the anthropometers.

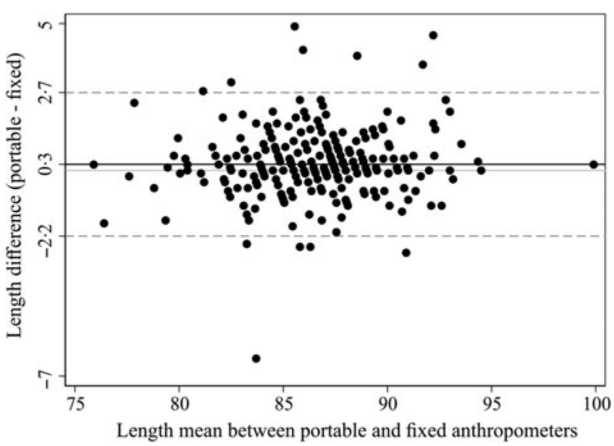

Fig. 1 Length difference and mean length between the portable and fixed anthropometers illustrated by Bland–Altman plot. Dashed horizontal lines represent the lower and upper limits of agreement, the solid grey line represents the zero difference and the solid black line represents the mean difference between the lengths from the portable and fixed anthropometers (Pelotas, Brazil; *N* 252)

Results in Table 3 support the high concordance between both anthropometers. The overall concordance was 0·94 (95 % CI 0·92, 0·95) and was marginally higher among girls compared with boys.

Discussion

After following the protocol established by this study, the portable anthropometer was found to be an accurate measure compared with the fixed anthropometer (gold standard), with high concordance between the estimates. To the best of our knowledge, this is the first study that compared length measurements of portable and fixed anthropometers among 24-month-old children. Other validation studies that focused on measuring individuals' body composition used indirect techniques[11,12].

The fixed anthropometer is the most robust way to accurately measure length of children up to 24 months of age, having a 0·1 cm precision. However, using this device to perform length measurements in home interviews might be difficult due to the large weight and size of the fixed anthropometer. To overcome this limitation, a portable anthropometer could be used, which is lighter and easier to carry compared with the fixed device. Yet, the portable device presents some limitations, such as being less precise (0·5 cm) and less durable since it is composed of a more fragile material. Even with these differences between the devices, our study showed that their measures were comparable.

According to the Brazilian Society of Pediatrics, children older than 24 months of age should preferably have their height measured by stadiometers fixed on a flat wall and without a footer[13]. However, the same society recommends that anthropometers positioned on a flat surface are used to measure height for children younger than 24 months of age. Although not recommended, the 2006 *Pesquisa Nacional de Demografia e Saúde da Criança e da Mulher* already used portable anthropometers to measure the length of children under 24 months of age[14].

A study used portable anthropometers to measure the length of children under 24 months of age, stating that it was a suitable device to measure children's height. However, the study did not perform any kind of validation[15]. Our manuscript fills a gap in the literature, confirming the high accuracy and validity of the portable anthropometer for the length measurement of 24-month-old children.

We observed heterogeneity in our sample distribution, with differences for income, maternal schooling and maternal skin colour. Most children belonged to families with income between two and three minimum wages, which could lead to differences in length measurements. This happens since income is a strong determinant of children's nutritional status[16–18], so as maternal skin colour and schooling[16]. The sample of our study can be considered representative of 24-month-old children. However, our validity results can only be generalised for studies comprising children of the same age group, that use the same portable anthropometer and that follow the same training and measurement procedures described in our protocol.

We did not find any statistically significant difference between the fixed and portable anthropometers, but the measurement error was a bit higher for boys compared with girls. One hypothesis for this finding is that boys were

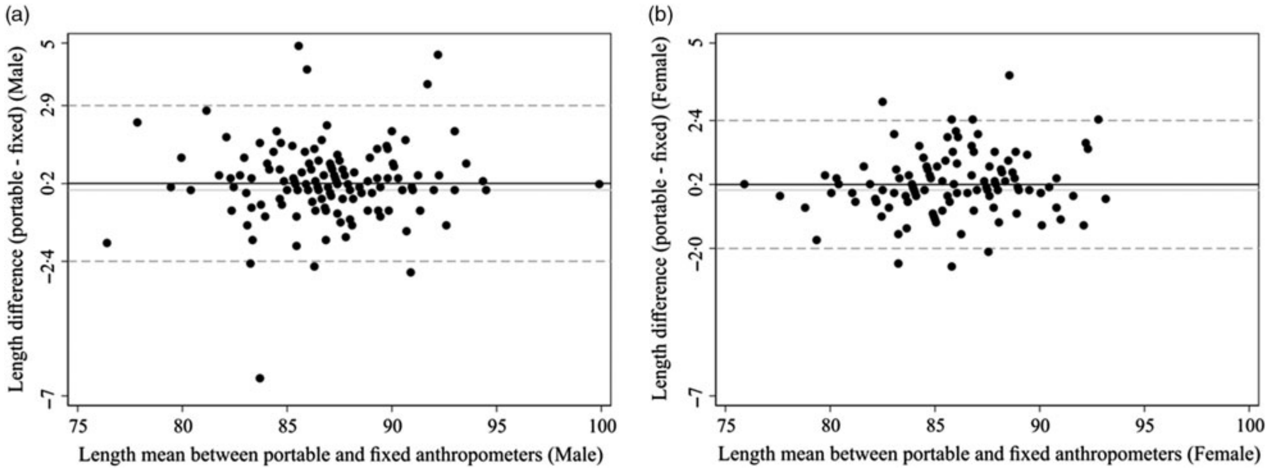

Fig. 2 Length difference and mean length between the portable and fixed anthropometers illustrated by Bland–Altman plot for (a) males and (b) females. Dashed horizontal lines represent the lower and upper limits of agreement, the solid grey line represents the zero difference and the solid black line represents the mean difference between the lengths from the portable and fixed anthropometers (Pelotas, Brazil; *N* 252)

Table 3 Overall length concordance, and stratified by sex, between the fixed and portable anthropometers (Pelotas, Brazil; *N* 252)

	ρ*	95 % CI
Overall	0·94	0·92, 0·95
Sex		
Female	0·95	0·93, 0·97
Male	0·92	0·90, 0·95

*Lin's concordance correlation coefficient.

more agitated during the measurement process, being harder to keep still and generating higher measurement error compared with girls. Although we could not empirically test this hypothesis in our study, related researches reported that girls were more focused and quieter compared with boys[19,20].

Some limitations of this study should be acknowledged. We selected the sample within a 2-month period of the year 2017, while the 24-month follow-up of the 2015 Pelotas (Brazil) birth cohort was taking place. Although our study comprised a limited period, it respected the natural flow of the birth cohort, so the sample used in this study is not characterised as a convenience sample. Furthermore, the total sample of the cohort is heterogeneous independently of the period of the year that it is followed-up. Thus, we believe that the characteristics of the subsample considered in our study would not influence the length measures and that this subsample can be considered representative of all the children who were followed-up during 2017. It is important to note that the 0·5 cm precision of the portable anthropometer could have a higher relative error when measuring the length of shorter and younger children. However, our findings are applicable only to children with 24 months of age. Our study presents as strengths the standardisation of the procedure to assess the length in different anthropometers, ensuring the comparability between the measurements, and the blinding between the independent evaluators to avoid contamination.

It is important to highlight that the measurements were performed in an ideal environment, where both anthropometers were placed in a flat and firm surface. However, this scenario could not be found in many contexts. Even so, according to the anthropometric protocol of length measurement in children up to 24 months of age, examiners should look for the most adequate surface possible to set the equipment (e.g. a table or the floor).

Under the standardised protocol followed in the present study, the portable anthropometer proved to be a valid instrument to measure the length of 24-month-old children. Considering its accuracy and the greater practicality to carry and set up, the portable anthropometer is a good option to be used in field work of large population-based studies. In addition, this study has great practical and clinical relevance since it will enable the use of portable anthropometers among 24-month-old children.

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