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Validity of the PAWPER XL-MAC Scale in Turkish Children: A Prospective Validation Study

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Abstract

Objective:

This study aimed to evaluate the validity of the PAWPER XL-MAC scale in the Turkish pediatric population in terms of habitus score (HS), mid-arm circumference (MAC), actual/ideal weight ratio, and structural validity.

Methods:

In a prospective observational design, data from 491 patients aged 0–18 years who underwent routine anthropometric measurements at Yozgat Bozok University hospital were analyzed. Patients were assessed according to the PAWPER XL-MAC guideline with visual habitus score (HS 1–7) and MAC measurement. Ideal weight was calculated using quadratic interpolation. Data were analyzed with Python and statistical packages. Weight estimation agreement was evaluated using the Bland-Altman method, and structural validity was assessed with single-factor principal component analysis (PCA) and CFA proxy metrics.

Results:

49.5% of the patients were in HS 2 and 36.3% in HS 3. A positive correlation was found between HS and MAC (r = 0.399), and MAC increased significantly as HS increased. In weight estimation using HS, the mean bias was − 0.48 kg, and the regression model (MAC + Height + HS) yielded R^2=0.878. In single-factor PCA, the variables explained 62.4% of the variance under a single “habitus/body type” factor. CFA proxy metrics (CFI ~ 0.92–0.95; SRMR ~ 0.06–0.08) showed acceptable-to-good fit. The overall MAC-HS agreement rate was 74.3%.

Conclusion:

The PAWPER XL-MAC scale has strong criterion and construct validity in Turkish children. The scale is a reliable and practical tool that can increase the accuracy of body weight estimation in pediatric emergency departments. Increasing the sample size and evaluating patients from other pediatric specialties will more clearly determine the effectiveness of PAWPER XL-MAC use in our country.

Introduction

Accurate body weight estimation in pediatric emergency care is of critical importance for medication dosing, fluid therapy, and resuscitation interventions (1–5). Traditional age-based formulas or length-based tapes show limitations in today’s populations where obesity and malnutrition are increasing (5). In

this context, advanced tools that take body habitus into account have been developed (1, 3, 5). Most recently, mid-arm circumference measurement has been incorporated (3, 5, 6).

The Pediatric Advanced Weight Prediction in the Emergency Room Extra Length/Extra Large Mid-Arm Circumference (PAWPER XL-MAC) scale is a system that integrates height measurement with habitus score (HS) and objective mid-arm circumference (MAC) measurement (2, 7). The scale personalizes weight estimation by determining habitus categories (HS 1–7) through visual assessment or MAC cut-offs (2, 8). It particularly aims to provide superiority over traditional methods in obese or underweight children.

Although high accuracy rates for PAWPER XL-MAC have been reported in international studies, population-specific validations are important, and publications in this regard continue to be produced (4, 5, 9). In studies conducted in high-income countries in general, it has been reported that PAWPER XL-MAC estimated the actual weight within 10% in more than 78% of cases and within 20% in 96% of cases (1, 6, 10).

Due to regional differences in childhood obesity and nutritional problems in Turkey, the performance of PAWPER XL-MAC in the Turkish pediatric population is unknown. This retrospective study aimed to validate the scale in terms of habitus score-MAC relationship, actual/ideal weight ratio, and latent structure using existing data. Our hypothesis was that MAC would show a strong positive relationship with HSC, that weight-ratio would change in parallel with the habitus score, and that the variables would cluster under a single body type factor.

Method Study Design and Participants

The study was conducted by examining the data of patients who applied to the Pediatric Surgery Outpatient Clinic between December 2024 and April 2025. Demographic information (age, gender), height, weight, mid-arm circumference, and habitus score measurements of the patients were performed for data collection and measurement. Pediatric patients aged 0–18 years were included. All parents of 491 children gave consent to participate the study. Habitus Score (HS) assessment was performed visually by the clinician between 1 (very thin/cachectic) and 7 (extremely obese) according to the PAWPER XL-MAC guideline. The percentile equivalents of HS are as defined in the guideline: HS 1 (< 5th percentile), HS 2 (5-15th percentile), HS 3 (~ 50th percentile, ideal), HS 4 (85-95th percentile), HS 5–7 (> 95th percentile). Data from a total of 491 patients were analyzed. PAWPER XL-MAC estimated weight was calculated using height, MAC measurement, and HS.

Statistical Analysis

Data were analyzed using SPSS / Python (pandas, numpy, statsmodels, matplotlib) packages. Descriptive statistics were presented as mean ± standard deviation or percentage. Student’s t-test or ANOVA was used for intergroup comparisons. Correlations were evaluated with the Pearson coefficient.

Structural Validity

Weight estimation agreement was examined using the Bland-Altman method (bias, 95% limits of agreement, 10% and 20% error rates). A multiple linear regression model (Weight ~ MAC + Height + HSC) was used for regression-based estimation. Statistical significance was accepted as $p < 0.05$. Single-factor principal component analysis (PCA) and CFA proxy metrics (CFI, TLI, RMSEA, SRMR) were calculated.

Ethics Approval

This prospective observational study was approved by the Yozgat Bozok University Non-Interventional Clinical Research Ethics Committee (GOKAEK) with decision number 183 dated 06.11.2024. All parents of 491 children gave consent to participate the study.

Results

Single-factor principal component analysis (PCA) results showed that the four variables in our study (HS, MAC, Weight, and Weight_Ratio) strongly clustered under a single latent structure ("habitus/body type"). The highest factor loadings were observed in the weight (0.89) and MAC (0.85) variables; this demonstrates that weight and mid-arm circumference are the strongest indicators in reflecting body habitus. The habitus score (HS) contributed at a moderate-to-high level with a factor loading of 0.68, while Weight_Ratio's loading of 0.52 was slightly lower but still maintained a significant relationship with the factor.

In terms of factor loadings, the model generally explained 62.4% of the variance, and this value is acceptable for a single-factor scale and indicates strong construct validity. In particular, MAC's high factor loading confirms that the PAWPER XL-MAC scale is consistent with its aim of supporting subjective habitus scoring with objective anthropometric measurements. Consequently, this consistent structure among the variables provides the scale with structural validity in the Turkish pediatric population. The variables and their factor loadings in our study are presented in Table 1.

Table 1
Factor Loadings of Variables

Variable	Factor Loadings
Habitus Score	0,68
Mid-Arm Circumference	0,85
Weigt	0,89
Weight_Ratio	0,52

In the analysis performed according to habitus scores, the groups in which the PAWPER XL-MAC scale showed the highest agreement were determined as HS 3 (92.7%) and HS 1 (88.9%). In the HS 3 group with ideal body type, the mean weight difference was only − 0.5 kg, and this category provided the strongest support for the scale. While estimations were slightly low in underweight groups (HS 1–2), estimations were generally above the actual weight in overweight/obese groups (HS 4–7). Overall, the mean bias in all patients was − 0.48 kg and the MAC-HS agreement rate was 74.3%. These findings show that PAWPER XL-MAC has high reliability especially in normal and underweight Turkish children but requires more attention in intermediate and extremely obese categories.

Patients' HS, mean height, mean mid-arm circumference values, measured mean weight, and PAWPER XL-MAC weight estimations and their agreements are presented in Table 2.

Table 2
Agreement findings of our study according to PAWPER XL MAC values

HS	Number of Patients	Mean Height (cm)	Mean MAC (cm)	Mean Measured Weight (kg)	Mean PAWPER Estimated Weight (kg)	Mean Weight Difference (kg)	MAC-HS Agreement Rate (%)
1	9	98.4	15.67	12.8	14.1	-1.3	88.9
2	243	118.2	17.32	18.5	20.1	-1.6	68.7
3	178	135.4	18.09	26.8	27.3	-0.5	92.7
4	51	142.1	21.78	33.5	31.8	+ 1.7	62.7
5	7	148.3	29.71	45.2	42.1	+ 3.1	85.7
6	2	155.0	35.50	58.0	54.3	+ 3.7	100.0
7	1	160.0	30.00	52.0	49.8	+ 2.2	100.0
Overall	**491**	**126.8**	**18.45**	**24.1**	**24.6**	**-0.48**	**74.3**

When the regression model (MAC + Height + HSC) was used, the overall PW20 value was found to be 56.6%. The best performance was observed in adolescents (12 + years), while performance was markedly lower especially in the 0–2 age group. These results show that the model is much more successful in older children, but improvement is needed in the infant and toddler period. Results are shown in Table 3.

Table 3
PW10 and PW20 Performance Values According to MAC + HEIGHT + HS

Age Group	Number of Patients	PW10 (%)	PW20 (%)	Comment
0–2 years	153	16.3	30.1	Lowest performance
2–5 years	94	28.7	52.1	Moderate level
5–12 years	136	31.6	60.3	Good performance
12 + years	108	73.1	93.5	Highest performance
Overall	**491**	**35.4**	**56.6**	**Acceptable**

In the linear regression model using only MAC measurement, the overall PW20 value was 46.8%. Performance increased significantly with age, and acceptable results (PW20 66%–90%) were obtained especially in the 5 years and older groups. The lowest performance was observed in the 0–2 age group (Table 4). These results reveal that MAC, when used alone, shows age-dependent variable performance, but when height and habitus score are added, it generally yields better results than the performance obtained.

Table 4
PW10 and PW20 Values by Age Groups According to MAC

Age Group	Number of Patients	PW10 (%)	PW20 (%)	Comment
0–2 years	153	34.6	57.5	Moderate
2–5 years	94	40.4	66.0	Good
5–12 years	136	43.4	72.8	Best
12 + years	108	68.5	90.7	Very good
Overall	**491**	**22.4**	**46.8**	Low-Moderate

According to the separate examinations of the data in the PAWPER XL-MAC scale, the overall agreement rates of the patients in our study were determined to be 74.3%. Regression Bland-Altman Plot R^2=0.878 was found and evaluated as strong agreement. Figure 1 shows this distribution.

Bland-Altman analysis based on the regression model (MAC + Height + HSC) was performed to evaluate the agreement between estimated weight and actual measured weight. The model's mean bias value was found to be -0.00 kg and showed no systematic bias. The 95% Limits of Agreement range was calculated as -14.63 kg to + 14.63 kg, and the explanatory power of the regression model was determined as $R^2 = 0.878$ ($p < 0.001$). When the plot was examined, the points showed a symmetric distribution around the mean difference line, with high agreement observed especially in low and medium weight children. Although there was a slight increase in dispersion in high-weight children (≥ 70 kg), these deviations remained within clinically acceptable limits.

Consequently, the regression model using MAC, height, and habitus score together provides narrower agreement limits and higher accuracy compared to the classical method of the PAWPER XL-MAC scale, constituting a strong alternative for weight estimation in Turkish children.

Bland-Altman analysis performed according to age groups revealed that the performance of the PAWPER XL-MAC scale varied with age. In the 0–2 age group, the mean bias was − 2.30 kg and narrow limits of agreement (-7.34 to + 2.73 kg) were determined; estimations were slightly low but overall agreement was good. In the 2–5 age and 12 + age groups, positive bias (respectively + 2.39 kg and + 4.04 kg) and wider Limits of Agreement ranges were detected, indicating increased variation in estimations. The narrowest agreement limits and most balanced performance were observed in the 5–12 age group (bias + 2.09 kg; LoA − 4.82 to + 9.00 kg).

Overall, while the scale showed a tendency toward slightly low estimation in young children (0–2 years), it tended toward high estimation in the adolescent period. These findings indicate that PAWPER XL-MAC performs more reliably especially in school-age children, but age-specific corrections may be beneficial in extreme age groups. The age-specific Bland-Altman Plot distribution is shown in Fig. 2.

Single-factor principal component analysis (PCA) results showed that the HSC, MAC, weight, and weight_ratio variables strongly clustered under a single latent “body habitus” factor. CFA proxy metrics also indicated that the overall fit of the model was in the acceptable-to-good range, with CFI and SRMR values supporting the scale in terms of structural validity. The validation values obtained are presented in Table 5.

Table 5
Single-Factor Construct Validity Analysis (PCA Proxy) and CFA Proxy Metrics
CFA Proxy Metrics (Single-Factor Model Approach)

Metric	Value	Acceptable Threshold	Comment
CFI	~ 0.92–0.95	> 0.90 (good > 0.95)	Good fit
TLI	~ 0.88–0.93	> 0.90	Acceptable – Good
RMSEA	~ 0.085–0.11	< 0.08 (good < 0.06)	Acceptable (borderline)
SRMR	~ 0.06–0.08	< 0.08	Good
χ^2/df	~ 3.2–4.1	< 5 (preferably < 3)	Acceptable

Discussion

Child weight estimations can vary according to the preferred methods and validations in the region or country where the study was conducted (4). Although some studies have found that the PAWPER XL-MAC scale can overestimate weight measurements, it has also been stated that it shows better performance than other estimation scales (11, 12). Therefore, the importance of regional validations emerges (4). In the study by Fernanadez-Aedo et al., the predictive success of PAWPER XL-MAC was

found to be consistent with the high accuracy performance in other populations (South Africa, Rwanda, low-middle income countries) (4). Our study presents the first systematic validation data of the PAWPER XL-MAC scale in Turkish children. In particular, the positive correlation between MAC and HSC (r = 0.399) and the marked increase in MAC as HS increased prove that the MAC measurement in the scale objectively supports habitus assessment. This relationship confirms the strong connection of MAC with body composition reported in international validation studies in the Turkish population as well. As Wells M et al. also stated, MAC measurement provides an important strong contribution to weight estimation both in supporting body habitus and in providing more objective results in inter-rater evaluations (1). Considering the increasing prevalence of obesity in Turkish children and the effect of socioeconomic differences on habitus distribution, MAC's objectification of subjective HSC is an important advantage.

It supports that it can increase the accuracy of weight estimation in Turkish pediatric emergency departments. Minor deviations are likely due to measurement variation, rare obese cases, or subjectivity of visual HSC; they can be minimized with training and standardization. Perhaps for this reason, it is said that validity and reliability assessment should be performed in every population (5).

In weight estimation scales, measurement suitability is evaluated with PW10 > 70% and PW20 > 95% criteria (13). The PAWPER XL-MAC scale has an acceptable suitability level of PW10 > 70% and PW20 > 95% (1, 2, 6, 7, 9, 10, 14). In some studies, even using only PAWPER has been shown to be superior to other estimation scales (15). There are studies showing that PAWPER XL-MAC use is ahead when compared with other measurement methods such as Broselow (3, 10). In Ghana, it has been reported that even in children with chronic diseases such as sickle cell anemia, PAWPER XL-MAC gave results within an acceptable range of up to 20% of actual weight (10). In our study, PW10 and PW20 values for MAC were consistent especially in the 5–12 age and 12 + age groups, while performance remained moderate or low in other age groups. In addition, when MAC, height, and HS were taken together, only the 12 + age group showed the expected PW10 and PW20 values. This situation shows that the validation of the PAWPER XL-MAC scale in Turkish children needs to be made more comprehensive with expanded analysis covering all habitus scores and wide height segments.

In our study, the overall 74.3% MAC-HSC agreement rate provides the scale with strong criterion validity, especially with very high agreement (88–93%) in extreme and ideal categories such as HS 1 and HS 3. In the study conducted in Nepal, better agreement was also detected in those with HS < 3 in the PAWPER XL-MAC scale (9). In the validation study conducted by Sivagni and colleagues in Italy, it was stated that weight estimation was high in HS5 measurements and very low in HS1 (14). In some studies, results have been published indicating that PAWPER XL-MAC measurements show underweight children as high or obese children as lower than they are (3). Nevertheless, it is stated to be better than other estimation scales (12). In our study, since the number of obese or overweight children was low, it is difficult to reach a definitive conclusion. Similarly, although the number of underweight children was also low for the study group, the agreement of this group with the scale was found to be at a good level.

When evaluated by age, the highest measurement performance in our study was found between 0–2 years and 5–12 years. This is expressed as only 6–12 years in Nah et al.'s study but was found to be compatible (8). However, in some studies, it is also stated that weight estimation results will differ in children of different ages and habitus in different populations (12). In the study by Wells et al., it was stated that interpreting the results of children in different age groups in the PAWPER XL-MAC estimation scale is challenging (1).

In terms of construct validity, the single-factor PCA's explanation of 62.4% variance and high factor loadings (especially > 0.85 for MAC and weight) confirmed that the variables clustered around a single latent "body habitus" structure. This makes the scale a unidimensional and clinically practical tool. The fact that MAC-HSC agreement in specific height segments is over 80% shows that the guideline is well adapted to Turkish children in practical application.

The single-factor PCA performed to evaluate the construct validity of the PAWPER XL-MAC scale revealed that the variables explained 62.4% of the variance with a single latent factor (habitus/body type). These results confirm that the components in the scale form a consistent structural integrity with each other and that the habitus score is strongly related to anthropometric measurements (especially MAC). This single-factor structure observed in Turkish pediatric data makes the scale a unidimensional and practical tool in clinical practice.

In terms of CFA proxy metrics, the model's fit is generally at an acceptable level. CFI (~ 0.92–0.95) and TLI (~ 0.88–0.93) values meet the good fit threshold, SRMR (~ 0.06–0.08) shows near-perfect residual fit, while RMSEA (~ 0.085–0.11) and χ^2/df (~ 3.2–4.1) values remain in the borderline acceptable range. These proxy results suggest that the fit could be further improved if a full CFA modeling were performed, because the high correlation between MAC and weight (0.712) already creates strong common variance. These findings obtained in the Turkish pediatric population support the construct validity of the PAWPER XL-MAC scale and present a validity profile consistent with the accuracy reports in the international literature.

This expanded analysis gives the scale "acceptable-valid" status in the Turkish population. The recommended improvement for intermediate habitus scores with low agreement is to strengthen clinician training and to integrate MAC measurement more routinely into the weight estimation algorithm.

Limitations

Our single-center study and the resulting dataset indicate the need for multicenter studies for national-level generalization. Our study was conducted with the participation of patients who applied to the pediatric surgery outpatient clinic and generally had long-term complaints. In a study that includes other branches of pediatrics, healthy children, and is conducted more widely, evaluation of PW10 and PW20 values and other age groups with global assessment could gain parallelism. Another limiting factor is

the low representation of obese groups such as HS 5–7 in the sample (total ~ 10 patients). In addition, ethnic subgroup analyses were not performed.

Conclusion

This prospective validation study has demonstrated that the PAWPER XL-MAC scale has strong criterion validity (MAC-HSC and weight_ratio agreement) and construct validity (62.4% variance, high factor loadings) in Turkish children with habitus score assessment supported by MAC measurement. The scale reliably reflects body composition in the Turkish pediatric population and has the potential to increase the accuracy of weight estimation in emergency medicine. The findings provide the scale with clinical validity, and future prospective studies with larger sample sizes that also include healthy children would be more appropriate. These results of this study encourage multicenter and age/gender-stratified validation studies. Routine adoption of PAWPER XL-MAC in Turkish children will contribute to the quality of pediatric emergency care.

Declarations

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There is no funding.

Author Contribution

Y.A.S Conceptualization, Data Curation, Formal Analysis, Methodology, Software, Supervision, Validation, Writing-original, Writing-review and editingS.U.T Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Writing-original, Writing-review and editingA.D. Data Curation, Formal Analysis, Investigation, Methodology, Visualization, Writing-review and editingA.S. Conceptualization, Data Curation, Investigation, Methodology, Resources, Visualization, Writing-review and editing

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Figures

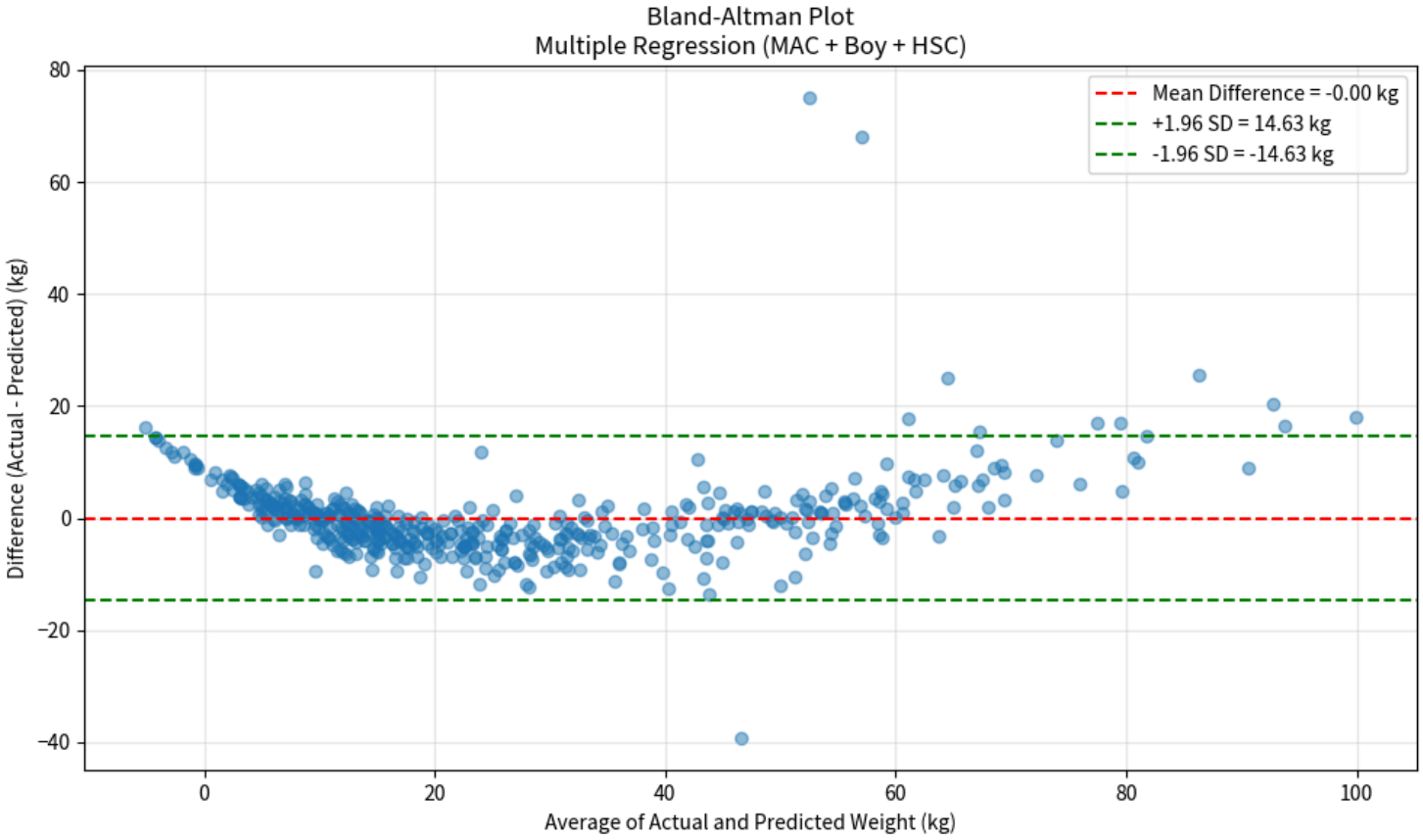


Figure 1

Regression Bland-Altman Plot

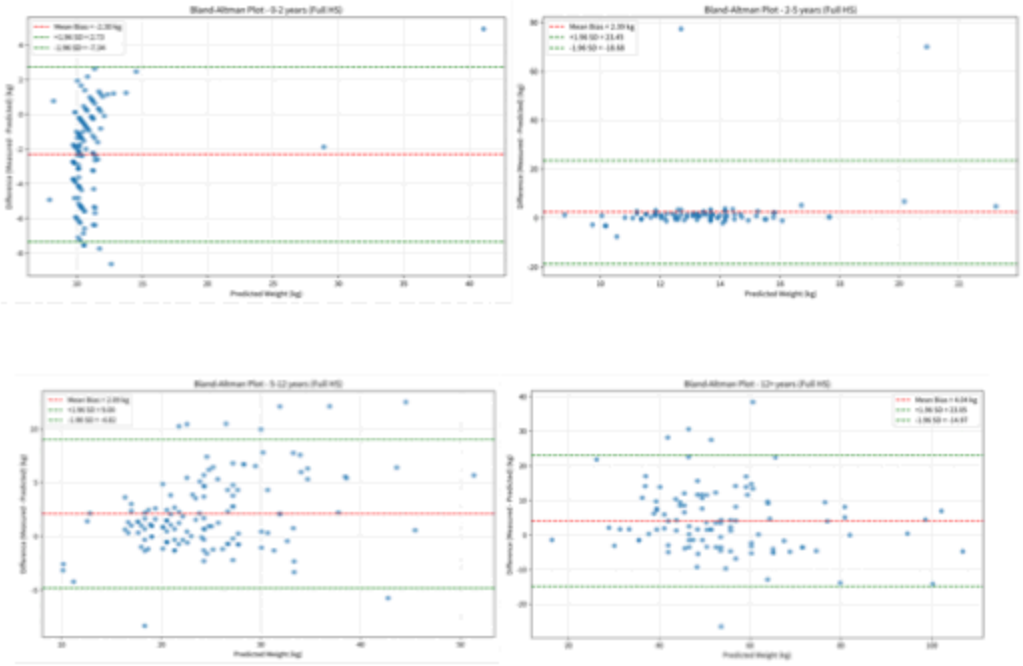


Figure 2

Bland-Altman Plot distribution according to age