Can Patient’s Body Weight Represent Body Diameter for Pediatric Size-Specific Dose Estimate in Thoracic and Abdominal Computed Tomography?

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ABSTRACT

Objective: The objective of the study was to determine whether body weight (BW) can be substituted for body diameters to calculate size-specific dose estimate (SSDE) in the children.

Materials and Methods: A total of 196 torso computed tomography (CT) studies were retrospectively reviewed. Anteroposterior diameter (D\text{AP}) and lateral diameter (D\text{lat}) were measured, and D\text{AP}+D\text{lat}, effective diameter, SSDE diameter and SSDE\text{BW} were calculated. Correlation coefficients among body diameters, all SSDE types and percentage changes between CT dose index volumes and SSDEs were analyzed by BW and age subgroups.

Results: Overall BW was more strongly correlated with body diameter (r = 0.919–0.960, P < 0.001) than was overall age (r = 0.852–0.898, P < 0.001). The relationship between CT dose index volume and each of the SSDE types (r = 0.934–0.953, P < 0.001), between SSDE\text{BW} and all SSDE diameters (r = 0.934–0.953, P < 0.001), and among SSDE diameters (r = 0.950–0.989, P < 0.001) overall had strong correlations with statistical significance. The lowest magnitude difference was SSDE\text{BW}−SSDE\text{eff}.

Conclusion: BW can be used instead of body diameter to calculate all SSDE types, with our suggested best accuracy for SSDE\text{eff} and the least variation in age < four years and BW < 20 kg.

Keywords: Body diameter, Body weight, Computed tomography dose index volume, Size-specific dose estimate, Torso

Key Messages: Size-specific dose estimate (SSDE) is a new and accurate dose-estimating parameter for the individual patient which is based on the actual size or body diameter of the patient. BW can be an important alternative for all body diameters to estimate size-specific dose or calculate SSDE in children.

INTRODUCTION

The use of pediatric computed tomography (CT) has grown dramatically in the past decade and the risk of radiation-induced cancers in children is of more concern than in adults. The most commonly used CT parameters for calculating CT radiation dosage are CT dose index volume (CTDI\text{vol}) and dose length product (DLP).[1-3] However, the CTDI\text{vol} is delivered from a specific standard phantom size and does not indicate the actual radiation dose applied to the individual patient, leading to underestimation of the total received radiation dose to children or adults with small body size.[1,2,4,5]

Size-specific dose estimate (SSDE) is a new parameter for individual specific patients which was developed by the American Association of Physicists in Medicine (AAPM Report 204).[9] The SSDE is
the patient dose estimate with corrections based on the actual size or body diameter of the patient.\textsuperscript{[49-10]} There have been several reports examining SSDE in children\textsuperscript{[1[1-15]} and the combination of measurements (sum of body diameters or effective diameters ($D_{\text{eff}}$) is recommended to determine the appropriate SSDE correction.\textsuperscript{[11]} Achieving a patient’s body diameters to calculate SSDE is more difficult than obtaining a patient’s body weight (BW) in routine work, which would make SSDE calculation more simple and rapid. However, only one report has examined conversion factors for pediatric SSDE\textsuperscript{[16]} The purposes of this study were to determine whether SSDE based on BW could be substituted for other SSDE values and to compare all SSDE values with CTDI\textsubscript{vol} among pediatric patients who underwent chest and abdominal CT.

METHODS

Patients and study design

The study was approved by our Human Research Ethics Committee. We retrospectively reviewed the imaging records of pediatric patients (<18 years) who underwent intravenous contrast chest or abdominal CT alone or contiguous chest and abdominal CT examinations from October 2011 to October 2016. Of the 2340 studies, 198 were randomly selected by computer, and two studies were excluded due to incorrect CT dose protocols.\textsuperscript{[17]} Finally, 196 studies were reviewed. The demographic data, age, BW, and gender of the patients were collected from the hospital medical records. The patients were categorized into age and BW subgroups. The age subgroups were 0–<5 years ($n = 71$), 5–<10 years ($n = 39$), 10–<15 years ($n = 31$), and 15–<18 years ($n = 55$). The BW subgroups were classified according to our institutional practice CT protocol: 4–9 kg ($n = 19$), 10–19 kg ($n = 70$), 20–29 kg ($n = 22$), 30–39 kg ($n = 15$), 40–49 kg ($n = 26$), and 50–64 kg ($n = 26$), >64 kg ($n = 18$).\textsuperscript{[18]}

Definitions, dosimetry, and body diameter measurement

Anteroposterior diameter ($D_{\text{AP}}$) was defined as the skin-to-skin thickness of the body part of the patient at the maximum thickness axial slice image [Figure 1]. Lateral diameter ($D_{\text{LAT}}$) was defined as the skin-to-skin thickness of the body part of the patient at the maximum thickness axial slice image and/or anterior-posterior dimension localizer image.\textsuperscript{[19]} Anteroposterior plus lateral diameter ($D_{\text{AP+LAT}}$) was defined as the diameter calculated as AP diameter plus $D_{\text{LAT}}$. The $D_{\text{eff}}$ was calculated as the square root of the AP dimension multiplied by the lateral dimension.\textsuperscript{[19]}

The CTDI\textsubscript{vol} (units: mGy) is the mean radiation absorbed dose to the patient at a given point of scan volume and is defined as weighted CTDI/pitch. The CTDI\textsubscript{vol} was calibrated using a pencil-shaped ionization chamber with either a dedicated 16-cm or 32-cm diameter polymethylmethacrylate phantom representing the head or a body region, respectively. The DLP was defined as the CTDI\textsubscript{vol} x exposed scan length. These parameters were displayed on the CT scanner consoles and Picture Archiving and Communication System (PACS). In multiphase-scanning, the CTDI\textsubscript{vol} of the maximum DLP was used. Only CTDI\textsubscript{vol} based on 32-cm phantom was included in this study. SSDE were calculated as CTDI\textsubscript{vol} multiplied by the conversion factor in the table and depended on BW, AP, and lateral and $D_{\text{eff}}$ according to the AAPM Report 204 and Khawaja et al. study.\textsuperscript{[19,16]} The exact conversion factor for each patient was calculated by the provided equations in the AAPM Report 204.\textsuperscript{[9]}

Data collection

The two CT scanner models used during the study period were a 64-multislice Philips Brilliance CT scanner and a 160-slice Toshiba Aquilion Prime CT scanner. The images were retrieved from a PACS workstation. The body diameters were independently measured by one 13-year-experience pediatric radiologist and one-third-year resident training in diagnostic radiology with consensus. The BW, age, dose indices (CTDI\textsubscript{vol} and SSDE\textsubscript{vol}, SSDE\textsubscript{BW}, SSDE\textsubscript{AP}, SSDE\textsubscript{LAT}, and SSDE\textsubscript{eff}), and body diameters (AP, lateral, AP+lat, effective) for each patient were recorded into a spreadsheet (Microsoft Office Excel 2010; Microsoft Corporation, Redmond, WA, USA).

Statistical analysis

We presented the quantitative parameters involving BW and body diameters (AP, lateral, AP+lat, effective) using median ± interquartile range (IQR) due to non-normal distribution data. Percentage changes between CTDI\textsubscript{vol} and each SSDE type and the magnitude differences between the SSDE\textsubscript{BW} and SSDE\textsubscript{diameters} were calculated.
Correlations among BW, age, dose indices, and body diameter measurements were established with Spearman Rank correlation coefficients \((r)\) for the following: Correlations between each body diameter and BW and between each body diameter and age; and correlations among dose indices (CTDI\(_{100}\), SSDE\(_{BW}\), SSDE\(_{AP}\), SSDE\(_{lat}\), SSDE\(_{AP+lat}\), and SSDE\(_{eff}\)) across BW and age subgroups. The power to determine sample size in BW and age subgroups for calculating correlation among dose indices was >0.8. Estimated relationships between median dose indices (CTDI\(_{100}\) and SSDE) and mean BWs were calculated by quantile regression analysis. Differences among the SSDE values were calculated by Wilcoxon Rank sum test. \(P = 0.05\) or less was considered to indicate a statistically significant difference. Interobserver agreement among the two reviewers were calculated using intraclass correlation coefficient (ICC) values.

**RESULTS**

**Demographic data**

This study included 196 CT studies from 196 patients, 112 male and 84 female, 72 contiguous chest and abdominal, 66 abdominal and 58 chest CTs. The median BW classified in BW and age subgroups are shown in Table 1. Males had a lower median BW (median [IQR], 18.50 [12.00–47.25 kg]) than females (median [IQR], 25.50 [13.15–46.23 kg]). The largest age subgroup was children 1 day–4 years (n = 71, 36.2%) and the 10–19 kg subgroup was the largest BW subgroup (n = 70, 35.7%).

**Dose metrics**

The overall CTDI\(_{100}\) at 32 cm phantom size was 2.90 (2.88–5.84 mGy) (median [IQR]).

**BW and body diameters across BW and age subgroups**

The overall body diameters, AP, lat, AP+lat, and effective, were median (IQR), 15.42 (13.19–19.05), 20.54 (17.55–27.21), 35.93 (31.17–46.66), and 17.81 (15.28–22.85) cm, respectively. The median body diameters across BW and age subgroups are shown in Table 1. The D\(_{eff}\) was larger than the AP diameter in all BW and age subgroups. All of the body diameters were in ascending order in both BW and age subgroups. Interobserver agreement using ICC between the two reviewers was excellent (ICC = 0.99).

**Correlation coefficients**

Overall and subgroup correlations between body diameters and BW and between body diameters and age are shown in Table 2. The D\(_{AP}\), D\(_{AP+lat}\), and D\(_{eff}\) were strongly correlated to the overall BW \((r = 0.919, 0.96, 0.935,\) and 0.943, respectively, \(P < 0.001\). The correlations between body diameters and overall age were also strong but less than the body diameter – BW correlations \((r = 0.852–0.898, P < 0.001)\) [Table 2].
The correlations across the SSDE BW and SSDE body diameters in the BW and age subgroups were moderate to strong with statistical significance \( (r = 0.719–0.979, P < 0.001 \) in the BW subgroups and \( r = 0.758–0.965, P < 0.001 \) in the age subgroups) [Table 3]. The correlations across the SSDE body diameters in the BW and age subgroups were strong with statistical significance as shown in Table 4 (\( r = 0.862–1, P < 0.001 \) in the BW subgroup and \( r = 0.872–0.9991, P < 0.001 \) in the age subgroup).

Quantile regression analysis

Quantile regression analysis was used to generate and predict the trends of the median dose indices (CTDIvol, SSDE BW, and all SSDE body diameters) and BW. The trends of all SSDE values were higher than the CTDIvol. The equations to predict dose indices from BW were:

\[
\text{CTDI}_{\text{vol}} = (0.09586 \times \text{BW}) + 1.475231 \quad \text{Equation 1}
\]

\[
\text{SSDE}_{\text{BW}} = (0.104456 \times \text{BW}) + 4.2285934 \quad \text{Equation 2}
\]

\[
\text{SSDE}_{\text{AP}} = (0.108038 \times \text{BW}) + 4.465022 \quad \text{Equation 3}
\]

\[
\text{SSDE}_{\text{lat}} = (0.104385 \times \text{BW}) + 4.915016 \quad \text{Equation 4}
\]

\[
\text{SSDE}_{\text{AP,lat}} = (0.104802 \times \text{BW}) + 4.753674 \quad \text{Equation 5}
\]

\[
\text{SSDE}_{\text{eff}} = (0.105634 \times \text{BW}) + 4.698292 \quad \text{Equation 6}
\]

Percentage change

The percentage change between CTDIvol and SSDE according to the BW and body diameters is shown in the box plot chart in Figure 2. Almost all SSDE values were greater than the CTDIvol. There was only one patient (0.5%) in which SSDE BW was less than CTDIvol (6%) and this patient weighed >100 kg. In the SSDE diameter group, eight SSDE diameters (SSDE AP = 1, SSDE lat = 2, SSDE AP,lat = 2, and SSDE eff = 3) were less than CTDIvol and all of them were maximum diameters in each SSDE diameter subgroup. The percentage change shown as median (IQR) was as follows: (SSDE BW−CTDIvol)/CTDIvol 88% (66–112%) and range −6–147%; (SSDE AP−CTDIvol)/CTDIvol 94% (61–119%) with range −39.82–171%; (SSDE lat−CTDIvol)/CTDIvol 111% (67–99%) with range −27–172%; (SSDE AP,lat−CTDIvol)/CTDIvol 104% (62–96%) with range −3–176%, and (SSDE eff−CTDIvol)/CTDIvol 101% (62–94%) with range −5–181%.

Differences between SSDE BW and SSDE diameters

The difference between SSDE BW and all SSDE diameters of each patient was not statistically significant in SSDE BW−SSDE AP (\( P = 0.3854 \)), and SSDE BW−SSDE AP,lat (\( P = 0.09188 \)), and SSDE BW−SSDE eff (\( P = 0.1167 \)) except in SSDE BW−SSDE lat (\( P = 0.03113 \)) by Wilcoxon Rank sum test. The SSDE magnitude differences

| Table 2: Spearman’s rank correlation coefficient values for BW, age, and diameter subgroups. |
|-------------------------------------------------|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                                 | AP diameter                     |                         | D_{lat}          | AP + D_{lat} s  | D_{eff}         |
|                                                 | Coefficient†                    |                           | Coefficient†     | Coefficient†    | Coefficient†    |
| BW subgroup                                     | <0.001                          | <0.001                     | <0.001           | <0.001          | <0.001          |
| Overall                                         | 0.919                           | 0.960                      | 0.935            | 0.943           | 0.922           |
| 4–9 kg (n=19)                                   | 0.722                           | 0.815                      | 0.552            | 0.465           | 0.418           |
| 10–19 kg (n=70)                                 | 0.638                           | 0.718                      | 0.77             | 0.706           | 0.450           |
| 20–29 kg (n=22)                                 | 0.102                           | 0.695                      | 0.46             | 0.418           | 0.147           |
| 30–39 kg (n=15)                                 | 0.522                           | 0.073                      | 0.39             | 0.450           | 0.092           |
| 40–49 kg (n=26)                                 | 0.082                           | 0.496                      | 0.58             | 0.490           | 0.010           |
| 50–64 kg (n=26)                                 | 0.340                           | 0.259                      | 0.34             | 0.382           | 0.059           |
| >64 kg (n=18)                                   | 0.864                           | 0.850                      | 0.91             | 0.922           | <0.001          |
| Age subgroup                                    | <0.001                          | <0.001                     | <0.001           | <0.001          | <0.001          |
| Overall                                         | 0.852                           | 0.899                      | 0.870            | 0.872           | <0.001          |
| 1 d–4 years (n=71)                              | 0.561                           | 0.761                      | 0.635            | 0.685           | <0.001          |
| 5–9 years (n=39)                                | 0.078                           | 0.250                      | 0.12             | 0.128           | 0.434           |
| 10–14 years (n=31)                              | 0.150                           | 0.264                      | 0.193            | 0.189           | 0.309           |
| 15–18 years (n=55)                              | 0.181                           | 0.278                      | 0.268            | 0.24            | 0.075           |

AP: Anteroposterior, †Spearman’s rank correlation interpretation (r): r = 1 perfectly positive, 0.8≤r<1 strongly positive, 0.5≤r<0.8 moderately positive, 0.1≤r<0.5 weakly positive, 0<r<0.1 lowest positive. BW: Body weight, D_{lat} lateral diameter, D_{eff} Effective diameter
between all SSDE\text{BW} and all SSDE diameters of each patient were plotted in graphs and categorized by age and BW subgroups (Figures 3 and 4). The lowest magnitude was the difference between SSDE\text{BW} and SSDE\text{eff} = -4.22–2.91, while the highest magnitude was between SSDE\text{BW} and SSDE\text{AP} = -4.18–7.3. The other magnitudes were -4.31–3.37 for SSDE\text{BW}–SSDE\text{lat} and -4.23–4.91 for SSDE\text{BW}–SSDE\text{AP+lat}.

DISCUSSION
Our study found that all body diameters and overall BW were strongly correlated (r = 0.919–0.960, P < 0.001). The D\text{lat}, D\text{AP+lat}, and D\text{eff} in our study had higher correlations with overall BW than with D\text{AP}, which could be explained by understanding the general growth pattern of children, in which the child's body grows in the

![Graph 1](image1.png)

**Figure 3:** Scatter plots of differences between SSDE\text{BW} and each SSDE body diameter by BW subgroups; SSDE\text{BW}–SSDE\text{AP} (a), SSDE\text{BW}–SSDE\text{lat} (b), SSDE\text{BW}–SSDE\text{AP+lat} (c), and SSDE\text{BW}–SSDE\text{eff} (d).

![Graph 2](image2.png)

**Figure 4:** Scatter plots of differences between SSDE\text{BW} and each SSDE body diameter by age subgroups; SSDE\text{BW}–SSDE\text{AP} (a), SSDE\text{BW}–SSDE\text{lat} (b), SSDE\text{BW}–SSDE\text{AP+lat} (c), and SSDE\text{BW}–SSDE\text{eff} (d).
Dwa more rapidly than in the AP diameter.\textsuperscript{[2]} The correlations for all body diameters and overall age were also strong but not as high as the body diameter-BW (r = 0.852–0.898, P < 0.001). However, the study by Kleinman \textit{et al.} found that the predicted individual patient size was not correlated with age.\textsuperscript{[2]}

All relationships of SSDE\textsubscript{BW}−all SSDE diameters (r = 0.934–0.953, P < 0.001) and among SSDE body diameters (r = 0.950–0.989, P < 0.001) with overall BW and with overall age showed strong and statistically significant correlations [Tables 3 and 4]. The strongest correlations were found in the 30–39 kg subgroup and the 5–9 years subgroup. Another previous study by Khawaja \textit{et al.} reached the same conclusion as our study that BW could be substituted to estimate size-specific dose in children.\textsuperscript{[16]} Another study by Parikh \textit{et al.} also found that BW could be used to estimate SSDE with reasonable accuracy at body width >20 cm.\textsuperscript{[14]}

In our study, we could predict the SSDE and CTDI\textsubscript{wat} using BW from Equations 1–6, while Christner \textit{et al.} study concluded that only CTDI\textsubscript{wat} increased linearly with patient size (D\textsubscript{lat} + D\textsubscript{wa}), while SSDE was independent of patient size.\textsuperscript{[10]} Furthermore, almost all SSDE type values (n = 189/196, 96.4%) were higher than CTDI\textsubscript{wat}, except for large-sized patients and those weighing >100 kg. Therefore, emphasizing CTDI\textsubscript{wat} underestimates the radiation dose in most pediatric or small-sized patients and overestimates the radiation dose in large-sized patients.\textsuperscript{[12,14,20]}

Although the SSDE\textsubscript{BW} had a statistically significant difference from SSDE\textsubscript{wat} by Wilcoxon Rank sum test, the magnitude difference between SSDE\textsubscript{BW} and SSDE\textsubscript{wat} was still in the acceptable range (within 7% of dose index in diagnostic radiology). The lowest magnitude difference was between SSDE\textsubscript{BW} and SSDE\textsubscript{AP}, while the highest magnitude difference was between SSDE\textsubscript{BW} and SSDE\textsubscript{Dwa}. These results could be explained by considering a study from Brady \textit{et al.}, which found that either an individual AP or Dwa measurement alone was less useful than a combination of AP and Dwa measurement for SSDE determination.\textsuperscript{[11]} However, all SSDE\textsubscript{BW}−SSDE\textsubscript{Dwa}, magnitude differences in our study were still in the acceptable range. The smallest variations of the SSDE differences in all subgroups by age and BW were in the lower BW ranges and younger age groups. In addition, most of the SSDE\textsubscript{BW} values tended to be lower than the SSDE\textsubscript{Dwa}. This implies that the SSDE\textsubscript{BW} can be substituted for SSDE\textsubscript{Dwa}, especially SSDE\textsubscript{eff}, but with caution as the SSDE\textsubscript{BW} tended to be lower than SSDE\textsubscript{Dwa}.

Our study had a few limitations. First, we could not statistically determine correlations between each body diameter and the BW <20 kg and >64 kg subgroups and between each body diameter and the age >4 year subgroups because the power of the sample size in those subgroups was <0.8. We suggest further research should be conducted with increased sample sizes in each subgroup if the study objective is to determine the correlation between body diameters and age or BW subgroups. Second, we did not calculate the SSDE from the water equivalent diameter (Dw), which is a physical parameter based on patient attenuation. In case of patients having high body attenuation, for example, those suffering from mediastinal or intra-abdominal tumors with low to normal BW, the SSDE\textsubscript{Dwa} is more accurate than SSDE\textsubscript{Dwa} to determine the correct patient dose.\textsuperscript{[21]} We suggest further studies including SSDE\textsubscript{Dwa} and clinical indications. Finally, the findings of our study may not be applicable in institutions and hospitals that have automatic software to determine the body measurements and SSDE.

**CONCLUSION**

Accurate dose-estimating parameters and size-specific dose indices are important for calculating accurate radiation dosage

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Table 3: Spearman’s rank correlation coefficient values for SSDE\textsubscript{BW}−SSDE diameter by BW and age subgroups.

| Parameter          | SSDE\textsubscript{BW}−SSDE\textsubscript{AP} | SSDE\textsubscript{BW}−SSDE\textsubscript{lat} | SSDE\textsubscript{BW}−SSDE\textsubscript{AP}\textsubscript{eff} | SSDE\textsubscript{BW}−SSDE\textsubscript{eff} |
|--------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------------|-----------------------------------------------|
|                    | Coefficient\(^1\) | P     | Coefficient\(^1\) | P     | Coefficient\(^1\) | P     | Coefficient\(^1\) | P     |
| BW subgroup        |                                |                                |                                |                                |                                |                                |                                |                                |
| Overall            | 0.934                           | <0.001                          | 0.951                           | <0.001                          | 0.942                           | <0.001                          | 0.953                           | <0.001                          |
| 4–9 kg (n=19)      | 0.926                           | <0.001                          | 0.938                           | <0.001                          | 0.893                           | <0.001                          | 0.860                           | <0.001                          |
| 10–19 kg (n=70)    | 0.719                           | <0.001                          | 0.751                           | <0.001                          | 0.802                           | <0.001                          | 0.733                           | <0.001                          |
| 20–29 kg (n=22)    | 0.899                           | <0.001                          | 0.933                           | <0.001                          | 0.940                           | <0.001                          | 0.935                           | <0.001                          |
| 30–39 kg (n=15)    | 0.957                           | <0.001                          | 0.975                           | <0.001                          | 0.975                           | <0.001                          | 0.979                           | <0.001                          |
| 40–49 kg (n=26)    | 0.908                           | <0.001                          | 0.946                           | <0.001                          | 0.960                           | <0.001                          | 0.955                           | <0.001                          |
| 50–64 kg (n=26)    | 0.949                           | <0.001                          | 0.939                           | <0.001                          | 0.953                           | <0.001                          | 0.956                           | <0.001                          |
| >64 kg (n=18)      | 0.976                           | <0.001                          | 0.938                           | <0.001                          | 0.968                           | <0.001                          | 0.962                           | <0.001                          |
| Age subgroup       |                                |                                |                                |                                |                                |                                |                                |                                |
| Overall            | 0.934                           | <0.001                          | 0.951                           | <0.001                          | 0.942                           | <0.001                          | 0.953                           | <0.001                          |
| 1–4 years (n=71)   | 0.807                           | <0.001                          | 0.824                           | <0.001                          | 0.758                           | <0.001                          | 0.823                           | <0.001                          |
| 5–9 years (n=39)   | 0.921                           | <0.001                          | 0.944                           | <0.001                          | 0.945                           | <0.001                          | 0.945                           | <0.001                          |
| 10–14 years (n=31) | 0.927                           | <0.001                          | 0.965                           | <0.001                          | 0.922                           | <0.001                          | 0.899                           | <0.001                          |
| 15–18 years (n=55) | 0.950                           | <0.001                          | 0.942                           | <0.001                          | 0.965                           | <0.001                          | 0.962                           | <0.001                          |

SSDE: Size-specific dose estimate, BW: Body weight, AP: Anteroposterior diameter, Dwa: Lateral diameter, AP+Lat: Anteroposterior plus Dwa, eff: Effective diameter. \(^1\)Spearman\’s rank correlation interpretation (r): 1 perfectly positive, 0.85≤r<1 strongly positive, 0.5≤r<0.8 moderately positive, 0.1≤r<0.5 weakly positive, 0<r<0.1 lowest positive.
There are no conflicts of interest.

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**Table 4: Spearman’s rank correlation coefficient values for SSDE body diameters by BW and age subgroups.**

| Parameter                  | SSDE<sub>AP</sub>-SSDE<sub>lat</sub> | SSDE<sub>AP</sub>-SSDE<sub>AP+lat</sub> | SSDE<sub>AP</sub>-SSDE<sub>eff</sub> | SSDE<sub>lat</sub>-SSDE<sub>AP</sub> | SSDE<sub>AP+lat</sub>-SSDE<sub>eff</sub> | SSDE<sub>lat</sub>-SSDE<sub>eff</sub> | P<sup>‡</sup> |
|----------------------------|--------------------------------------|----------------------------------------|-------------------------------------|-----------------------------------|--------------------------------------|------------------------------------|------|
| **BW subgroup**            |                                      |                                        |                                     |                                   |                                      |                                    |      |
| Overall                     | 0.950                                | 0.989                                  | 0.966                               | 0.978                             | 0.979                                | 0.986                              | <0.001 |
| 4–9 kg (n=19)              | 0.989                                | 0.938                                  | 0.895                               | 0.997                             | 0.898                                | 0.881                              | <0.001 |
| 10–19 kg (n=70)            | 0.932                                | 0.978                                  | 0.961                               | 0.983                             | 0.982                                | 0.967                              | <0.001 |
| 20–29 kg (n=22)            | 0.891                                | 0.969                                  | 0.973                               | 0.961                             | 0.997                                | 0.952                              | <0.001 |
| 30–39 kg (n=15)            | 0.982                                | 0.982                                  | 0.985                               | 1.000                             | 0.996                                | 0.996                              | <0.001 |
| 40–49 kg (n=26)            | 0.862                                | 0.950                                  | 0.956                               | 0.962                             | 0.998                                | 0.959                              | <0.001 |
| 50–64 kg (n=26)            | 0.917                                | 0.976                                  | 0.977                               | 0.969                             | 0.9992                               | 0.964                              | <0.001 |
| >64 kg (n=18)              | 0.953                                | 0.976                                  | 0.982                               | 0.988                             | 0.997                                | 0.985                              | <0.001 |
| **Age subgroup**           |                                      |                                        |                                     |                                   |                                      |                                    |      |
| Overall                    | 0.950                                | 0.989                                  | 0.966                               | 0.978                             | 0.979                                | 0.986                              | <0.001 |
| 1 d–4 years (n=71)         | 0.880                                | 0.982                                  | 0.895                               | 0.941                             | 0.937                                | 0.973                              | <0.001 |
| 5–9 years (n=39)           | 0.971                                | 0.986                                  | 0.990                               | 0.993                             | 0.9991                               | 0.991                              | <0.001 |
| 10–14 years (n=31)         | 0.872                                | 0.956                                  | 0.935                               | 0.971                             | 0.977                                | 0.943                              | <0.001 |
| 15–18 years (n=55)         | 0.917                                | 0.972                                  | 0.978                               | 0.979                             | 0.998                                | 0.975                              | <0.001 |

SSDE: Size-specific dose estimate, BW: Body weight, AP: Anteroposterior diameter, D<sub>lat</sub>: lateral diameter, AP+lat: Anteroposterior plus D<sub>lat</sub>, eff: Effective diameter.

*Spearman’s rank correlation interpretation (r): r=1 perfectly positive, 0.8≤r<1 strongly positive, 0.5≤r<0.8 moderately positive, 0.1≤r<0.5 weakly positive, 0<r<0.1 lowest positive.* 

‡P values for Spearman’s rank correlation coefficient in SSDE<sub>AP</sub>-SSDE<sub>lat</sub>, SSDE<sub>AP</sub>-SSDE<sub>AP+lat</sub>, SSDE<sub>AP</sub>-SSDE<sub>eff</sub>, SSDE<sub>AP+lat</sub>-SSDE<sub>eff</sub>, SSDE<sub>lat</sub>-SSDE<sub>AP</sub>, SSDE<sub>AP+lat</sub>-SSDE<sub>eff</sub> and SSDE<sub>lat</sub>-SSDE<sub>eff</sub>.
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