Effect of a Novel Procedure for Limiting Motion on Body Composition and Bone Estimates by Dual-Energy X-Ray Absorptiometry in Children

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We studied the effect of using the BodyFIX (Medical Intelligence Inc, Schwabmunchen, Germany) to immobilize children during a dual-energy X-ray absorptiometry scan on body composition and bone estimates. Overestimates of soft tissue and bone introduced by the BodyFIX were avoided by using a modified version of the system or were corrected by using mathematical models developed in this study. *(J Pediatr 2011;159:691-4)*

There is evidence that dual-energy X-ray absorptiometry (DXA) is an accurate and reliable method for assessing body composition and bone of children.[1,2] However, motion artifact can result while scanning children with movement disorders[3,4] and lead to unpredictable alterations in the assessment of fat mass, fat-free soft tissue mass (FFST), and bone mineral content (BMC).[5] One potential way to minimize motion artifact during a DXA is to immobilize children by using the BodyFIX (Medical Intelligence Inc, Schwabmunchen, Germany), which is a novel, vacuum pressure-based immobilization system. Although the BodyFIX has been used to limit motion of children with movement disorders,[6,7] studies are needed to determine the effect of the BodyFIX on body composition and bone estimates by DXA. The purpose of our study was to determine if using the BodyFIX to limit motion during a DXA alters body composition and bone estimates in children.

Methods

Children (5-14 years old) without a movement disorder were recruited to participate in the study. The study was approved by the institutional review board at the University of Delaware. The participants' parents provided written consent and participants provided written assent. Body mass was measured to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm. Scans of the whole body were conducted by using DXA (Delphi W, software version 11.2, Pediatric Whole Body Analysis; Hologic Inc, Bedford, Massachusetts). One scan was conducted by using the protocol recommended by the manufacturer (ie, standard protocol). A second scan was conducted while the participant was immobilized from the waist down by using the BodyFIX (**Figure 1**; available at www.jpeds.com). A third scan was conducted while the participant was immobilized from the waist down by using a modified version of the BodyFIX in which the BlueBAG was excluded (**Figure 1**). The BlueBag is a large deflatable pillow that the participant lies on during the BodyFIX procedure. It creates a mold around the participant when the air is removed. The DXAs were completed in a random order.

Fat mass, FFST, percentage body fat, and total mass of the whole body were determined by using analysis procedures recommended by the manufacturer. Because the head is disproportionately large in young children and may mask bone deficits,[8] it was not included in the analysis of BMC, areal bone mineral density (aBMD), and bone area. Repeated testing of whole-body composition and bone conducted in 20 children (5-14 years old) after repositioning had an intraclass correlation coefficient >0.99 and coefficient of variation <1% for all measures.

Statistical Analysis

Data were analyzed by using SPSS version 17.0 (SPSS Inc, Chicago, Illinois). A 1-way ANOVA with repeated measures and a Bonferroni correction was used to determine if there were differences in body composition and bone estimates when using DXA with the BodyFIX, with a modified version of the BodyFIX, and without the BodyFIX. Linear regression analysis and Bland-Altman plots were used to assess the agreement among fat mass, FFST, and bone estimates by DXA with the BodyFIX, with a modified version of the BodyFIX, and without the BodyFIX. Pearson correlation analysis was used to determine the relationship between the difference in body composition and body mass estimates with and without the BodyFIX and markers of body size and/or thickness (ie, body mass measured by using a scale and body mass index [BMI]). Mathematical models were developed by using linear regression analysis and the estimates of body composition or bone by DXA without the BodyFIX as the dependent variable and estimates of body composition or bone by DXA with the BodyFIX as the independent variable. The models were cross-validated by using the leave-one-out method.[9] The alpha level was set at .05.

aBMD	Areal bone mineral density
BMC	Bone mineral content
BMI	Body mass index
DXA	Dual-energy X-ray absorptiometry
FFST	Fat-free soft tissue mass

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Table I. Physical characteristics, body composition, and bone estimates of 5-14-year-old children (n = 30)

	Mean (SD)
Age (y)	9.4 ± 2.6
Height (m)	1.39 ± 0.17
Height percentile	66 ± 22
Body mass (kg)	34.7 ± 11.2
Body mass percentile	64 ± 22
BMI (kg/m^2)	17.5 ± 2.4
BMI percentile	59 ± 27
Fat mass (kg)	
DXA	8.2 ± 3.3
DXA + BFIX	9.3 ± 3.5*
DXA + MBFIX	8.2 ± 3.2
FFST (kg)	
DXA	24.6 ± 8.4
DXA + BFIX	24.9 ± 8.5*
DXA + MBFIX	24.7 ± 8.4
Body mass (kg)	
DXA	34.1 ± 10.9
DXA + BFIX	35.5 ± 11.3*
DXA + MBFIX	34.2 ± 10.9*
%Fat	
DXA	24.1 ± 6.4
DXA + BFIX	26.4 ± 6.2*
DXA + MBFIX	24.2 ± 6.2
BMC (g)†	
DXA	943 ± 392
DXA + BFIX	958 ± 393*
DXA + MBFIX	950 ± 402
aBMD (g/cm^2)†	
DXA	0.672 ± 0.114
DXA + BFIX	0.679 ± 0.115*
DXA + MBFIX	0.670 ± 0.116
Bone area (cm^2)†	
DXA	1353 ± 348
DXA + BFIX	1361 ± 344
DXA + MBFIX	1363 ± 353

DXA + BFIX, estimates by DXA with the BodyFIX; *DXA + MBFIX*, estimates by DXA with a modified version of the BodyFIX (ie, no BlueBAG).
*Different from DXA, $P < .05$.
†Values are minus the head.

Results

Physical characteristics and DXA estimates of the participants (16 boys and 14 girls) are shown in Table I. Total fat mass, FFST, body mass, BMC, and aBMD from DXA were 15 ± 6%, 1 ± 1%, 4 ± 1%, 2 ± 2%, and 1 ± 2% higher, respectively (all $P < .01$), and percentage body fat was 2.2 ± 0.9 percentage points higher ($P < .001$) with than without the BodyFIX. However, the modified BodyFIX had no detectable effect on soft tissue or bone estimates by DXA ($P > .22$). Body mass from DXA was higher with than without the modified BodyFIX, but the increase was very small (0.16 ± 0.25 kg, $P = .001$).

There were very strong relationships between DXA estimates of soft tissue and bone by DXA with vs without the BodyFIX ($r^2 > 0.98$) (Figure 2). The overestimation of fat mass by DXA when using the BodyFIX is demonstrated by the regression line below the line of identity in Figure 2 and by the Bland-Altman plot in Figure 3 (available at www.jpeds.com). Although the slight overestimation of FFST and BMC when using the BodyFIX is difficult to detect in the scatter plots (Figure 2), it is evident in the Bland-Altman plots (Figure 3). The pattern for aBMD was similar (not shown). There was strong agreement between soft tissue and bone estimates by DXA with vs without the modified BodyFIX (Figures 2 and 3).

The differences in fat mass and body mass from DXA with vs without the BodyFIX were positively related to body mass measured by using a scale ($r = 0.636$ and 0.870, respectively; $P < .001$) and BMI ($r = 0.408$ and 0.536, respectively; $P < .05$). The difference in FFST by DXA with vs without the BodyFIX was significantly related to body mass ($r = 0.368$; $P = .046$) but not BMI ($r = 0.159$; $P = .403$). The differences in BMC and aBMD with vs without the BodyFIX were not significantly related to body mass or BMI ($r < 0.2$; $P > .3$).

Following the leave-one-out cross-validation analysis, fat mass, FFST, BMC, and aBMD estimated from DXA with the BodyFIX and the models presented in Table II (available at www.jpeds.com) agreed extremely well with estimates by DXA without the BodyFIX, as indicated by the very high degree of variance explained ($r^2 > 0.98$), low standard errors (429 g, 411 g, 25 g and .12 g/cm^2, respectively), and lack of significant or meaningful differences ($P > .95$).

Discussion

One potential reason for the overestimation of soft tissue and bone measures by DXA when the BodyFIX was used to limit motion was the additional material. Koo et al[3] found that the inclusion of a cotton blanket and/or a diaper when scanning infants increased estimates of FFST and body mass ($P < .001$). The BodyFIX includes a 4.9 kg BlueBAG on which the participant lies. It also includes a plastic-like foil, stabilizing cushions, and tubing, which have a combined mass of approximately 0.6 kg. Interestingly, when all of the additional material from the BodyFIX was included in the DXA, only approximately 27% of the actual mass of the material was added to total body mass estimates. When the BlueBAG was removed from the scanning region by using a modified version of the BodyFIX, there no longer was an overestimation of fat mass, FFST, BMC, or aBMD, and body mass was overestimated by approximately 0.5%.

Another factor that may have contributed to the increase in soft tissue and bone estimates when using the BodyFIX was the increased participant thickness when placed on the BlueBAG, which is approximately 5-cm thick. There is evidence that simulated increases in body thickness can lead to increased fat mass and aBMD estimates by DXA,[10] which is consistent with the present study. Furthermore, changes in the distance of the body from the X-ray source can alter the degree of magnification associated with fan-bean DXA instruments. BMC and bone area should decrease proportionately and aBMD should be unaffected as the distance between the participant and the table increase.[11] However, this is not consistent with the present study, because BMC and aBMD