Insights From Body Composition Studies

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Twelve percent of children under 2 years[1] and 10% of 2–5 year olds are obese (National Health and Nutrition Examination Survey; body mass index [BMI] ≥95th percentile)[2] with ≈70% remaining obese in adulthood.[3] In females of childbearing potential the prevalence of obesity is approaching 30% and appears to be trending upwards.[4] This rise in the percentage of overweight/obese pregnant women is worrisome given the negative long-term health consequences incurred by their offspring.[5] Over the last 3 to 5 years, exciting technology has emerged allowing clinicians/researchers to measure whole body composition accurately, quickly, and noninvasively in infants as young as 5 days old. This development allows for the first time the opportunity to study the link between maternal BMI and offspring body composition early in life, which could yield valuable insights into innovative strategies for obesity and diabetes prevention programs. Therefore, the purpose of this presentation summary is to first review whole body composition techniques used in pediatric populations. With this in mind, the second purpose is to review the current state of the literature linking maternal obesity and offspring body composition early in life.

In pediatric populations, body weight or BMI percentiles define overweight/obesity risk. An important but often overlooked issue using this approach is that the quality of the weight is left unaccounted. The following two examples highlight this point (unpublished data; body composition measured by dual-energy X-ray absorptiometry [DXA]). In example 1, two 5-year-old girls have the same BMI (16.3 kg/m^2; 73rd percentile) but have a 5% fat unit difference in %fat (29.1% vs 24.5%) and a 26% difference in trunk fat mass (2,022 g vs 1,495 g) (see Fig 1).

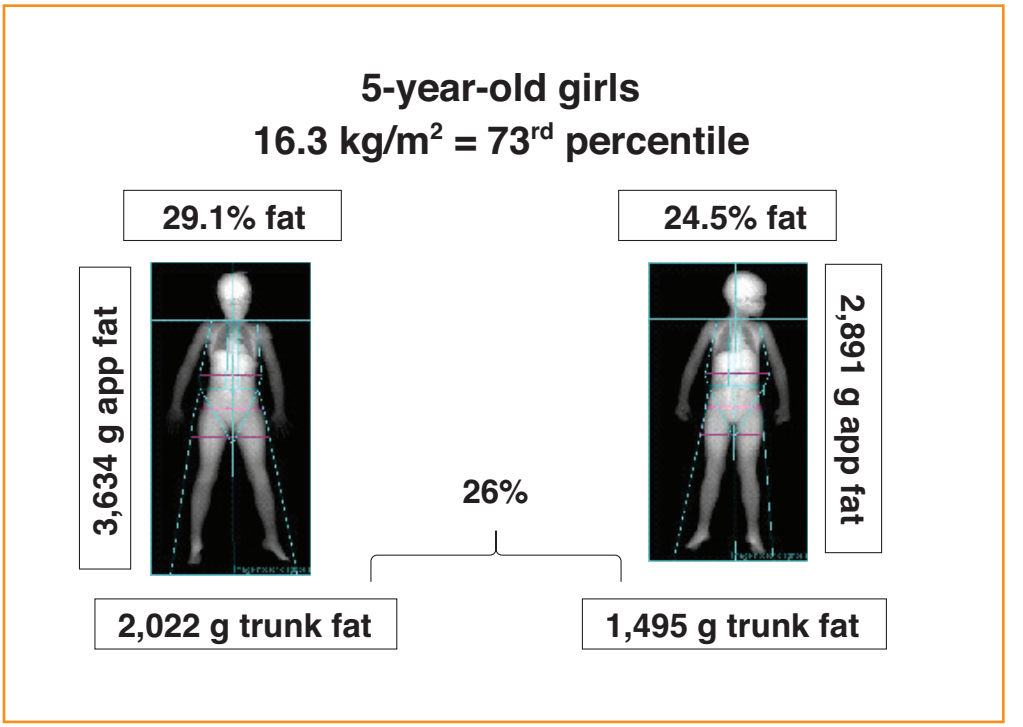

Fig 1. Dual-energy X-ray absorptiometry (DXA) of two young girls with the same BMI.

In example 2, two 6-month old girls weighing 6.68 kg have a 4% fat unit difference in %fat (30.9% vs 34.9%). Both examples demonstrate the importance for accurate body composition assessment. The measurement of body composition allows clinicians to individualize treatment plans in growth- and development-related matters in their patients, while giving researchers the ability to disentangle complicated observational data linking early life events with long-term morbidity.

Two commonly available research-based whole body composition techniques in pediatric populations are air-displacement plethysmography (ADP) and DXA. Of note, these techniques are not limited to pediatric populations but their application to pediatric populations is new.

The basic underlying principles of ADP originated in the early 1900s in Germany[6,7] with the foundational basis of a feasible, practical, accurate, and valid ADP described in detail by Dempster and Aitkens in 1995.[8] The first validated published data using ADP in an adult population also appeared in 1995.[9] In brief, ADP (BOD POD®; COSMED USA Incorporated, Concord, CA, see Fig 2) comprises a single unit dual-chamber plethysmograph consisting of both a testing and reference chamber with whole body volume determined by the ratio of the pressure amplitudes

between the two chambers.[8] In 2000, ADP was validated for the first time in children (≈10–12 yrs)[10] and in 2003, ADP (PEA POD® , see Fig 2) accurately measured body volume in infants <8 kg.[11,12] ADP is an attractive technology given its application across the spectrum of ages and body weight, ie, ADP can measure infants as small as ≈ 4 kg while accommodating morbidly obese individuals weighing >150 kg.

Fig 2. Air-displacement plethysmography: Body composition tracking systems.

Source: http://www.cosmed.com/index.php?option=com_content&view=article&id=971&Itemid=304&lang=en

DXA determines body composition by measuring attenuated X-rays emitted at two energy levels (40 and 70 kV), with the ratio between the low-energy and high-energy sources being 1.21 and 1.369 for fat and soft lean tissue respectively.[13] DXA is an exciting technology given its ability to provide regional body composition estimates. A recent paper indicated that DXA in newborn infants was reliable and was a reasonable reference tool for estimating body composition.[14] As with ADP, DXA can accommodate a wide range of ages and body sizes; however, some institutional review boards do not allow testing in young children given the small dose of radiation.

Parental obesity, especially on the maternal side, more than doubles the risk of the offspring being obese as an adult.[15-17] Maternal obesity conferring increased adiposity in their offspring is multifactorial with likely candidates being genetic and epigenetic factors, overnutrition, maternal BMI and gestational weight gain,

socioeconomic factors, and environmental factors to name but a few.[18] It is important to understand that maternal adiposity is not restricted solely to pregravid obesity, but also to gestational weight gain. Both contribute to increased maternal circulating glucose and fat concentrations, which lead to increased fetal insulin secretion and increased fetal growth. An excellent review article presents the body of the literature on the association between maternal obesity and offspring obesity throughout the lifespan.[4]

Briefly, and focusing narrowly on neonates, it has been shown within the first 2 to 3 weeks of life offspring from overweight/obese mothers (defined by a BMI of >25 kg/m^2) were significantly fatter (determined by ADP) on both an absolute (414 vs 264 g fat; $P<0.05$) and relative (13.6 vs 12.5 %fat; $P<0.001$) basis compared to offspring from normal weight mothers (see Table below).[19]

Table. Neonatal Body Composition at 3 Weeks[19]

	Normal (N=38)	Overweight/Obese (N=44)	*P* Value
Gestational age (wks)	39.5 ± 1.2	38.9 ± 1.0	0.03
Age at testing (days)	19.5 ± 8.5	19.8 ± 9.3	0.91
Birth length (cm)	50.7 ± 2.6	49.6 ± 2.6	0.08
Birth weight (g)	3433 ± 396	3368 ± 400	0.44
% body fat	12.5 ± 4.2	13.6 ± 4.3	0.00
Fat mass (g)	414 ± 264	448 ± 262	0.04
Fat-free mass (g)	3311 ± 345	3162 ± 343	0.03

Furthermore, increased fat mass in offspring from overweight/obese mothers is present as early as 72 hours postpartum.[20] Sewell et al[20] reported offspring from overweight/obese mothers were significantly fatter (determined by total body electrical conductivity) (11 vs 9.6 %fat; $P<0.01$) compared to offspring from normal weight mothers, while having significantly greater absolute fat mass (406 vs 331 g fat; $P<0.01$). Interestingly, Catalano and Kirwan[21] reported significant whole body composition (determined by total body electrical conductivity) differences starting at birth between offspring from normal weight and obese mothers (11.6 vs 13.1 %fat

[percent fat for entire body]; $P<0.001$; 384 vs 448 g fat [absolute amount of fat in body]; $P<0.01$). These relationships between maternal obesity and offspring adiposity persist unabated into adulthood with long-term obesity, diabetes, and cardiovascular morbidity certain.

In conclusion, over the last 10 years technological advances have given clinicians and researchers the opportunity to accurately, quickly, and reliably estimate whole body composition in infants as young as 5 days old. This is an important development given the link between maternal obesity and offspring adiposity and highlights the need for valid methods to unravel this knotty problem. Though the literature is developing, it appears maternal obesity increases the likelihood of their offspring being obese later in life with a significant impact present starting at birth.

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Q & A

Q: At birth, the lean body mass of a fetus is about 80% water. Do you think that the changes you see at 3 months could be a reflection of the change in water mass rather than bone mass or muscle mass? When we diurese that extra water in the fetus, we end up with a decrease in lean body mass.

Dr Fields: That is a good point. My data do not show that because I usually do not start dosing children until about 6 months of age. We probably should try to start earlier.

Q: From a functional point of view, it is probably important to know exactly where the fat is. Would you comment on such issues as looking at fat position in the liver, which drives you to discuss ultrasound and magnetic resonance imaging (MRI)—techniques other than those you described?

Dr Fields: That is where I want to go, but as everyone keeps saying, MRI equipment costs money, so I will need a big grant to get it. It is easy to do these sorts of tests in very young infants after you feed them. Compliance is good.

Q: I know you have measured skinfolds on neonates, as well. Will you compare your other methods with the skinfold measurements?

Dr Fields: I measure at least five sites: the abdomen, chest, thigh, tricep, and subscapula. The measurements are in my database, but I have not done much with them, nor have I compared this to other methods. We measure the mothers as well.

Q: Do you have any experience with ultrasound in utero?

Dr Fields: I am trying to collaborate with some of my friends in obstetrics because they do ultrasounds in utero. We have not done that ourselves yet.

Q: And in children postnatally?

Dr Fields: No, because it has been difficult to obtain the time in radiology. As a researcher, I want to know that I can bring a subject in at 8:00 and get it done. The radiology staff does not want to do that. Or they want me to come in Saturday at 7:00 in the morning. Clearly, that is not going to work.

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Q: You showed that at 3 weeks there are already differences in lean body mass and fat mass in infants. Did you control for feeding practices?

Dr Fields: We looked at the data many different ways but we did not control for feeding practices.

Q: Do you believe there were more breastfed than formula-fed infants in your sample?

Dr Fields: In our sample, 60% were breastfed and 40% were formula fed.