COMPARISON OF ADIPOSITY AND BODY COMPOSITION METHODOLOGY IN PRETERM AND TERM INFANTS

by

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STATEMENT OF THESIS APPROVAL

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ABSTRACT

Infant prematurity is associated with acute health risks and altered fat deposition. Aberrations in fat deposition put preterm infants at a higher risk for developing conditions such as hypertension and glucose intolerance in later life. Thus, the recommended catch-up growth for preterm infants, which only examines weight gain, may have detrimental consequences for future metabolic health. Validated, low-risk methods of accurately determining body fat deposition will assist medical professionals in monitoring interventions and optimizing growth quality in preterm infants.

This study compared body fat composition in infants that were born preterm (n = 28) between 32-36 weeks postmenstrual age (PMA) and born term (n = 28) between 38-41 weeks PMA at the University of Utah Hospital. Relationships between percent body fat (%BF) measured by air displacement plethysmography (ADP) and anthropometry/skinfolds were determined. Gender and ethnic distribution were similar between the preterm and term cohorts. Age adjusted body weight, length, head circumference, and body mass index were significantly lower for preterm infants ($p < 0.001$). Despite the smaller body size and less mature PMA at hospital discharge, preterm infants had higher %BF by ADP ($p = 0.057$). In addition, mid-arm circumference was a good predictor for preterm infant %BF ($p < 0.001$). Our results show that preterm infants develop increased body fat percentage as they approach term-corrected age compared to term infants. This result may explain the connection between

a preterm birth and metabolic consequences later in life. This study provides support for the importance of monitoring body composition in preterm infants to ensure proper growth quality.

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INTRODUCTION

Background/Literature Review

A premature birth is defined as an infant delivery before 37 weeks gestation (1). In the United States, the preterm birth rate increased from 9.4% of births in 1981 to 12.8% in 2006. However, recent birth certificate data indicate that the preterm birthrate decreased for the first time in three decades, with a 4% decline from 2006 to 2008. According to the Centers for Disease Control and Prevention, the reason for the lower rate is unknown (2). The decline in preterm birth rate is consistent among mothers of all age groups under 40 and for all types of deliveries (2). Despite the decrease in rate, a premature birth is still associated with increased morbidity and higher hospital costs (1). Acute health risks associated with prematurity include low birth weight (< 2500 g), underdeveloped lungs, jaundice, and infections. Potential long-term health effects of prematurity include serious lung conditions, vision and hearing loss, learning disabilities, poor postnatal growth, and altered adiposity (3).

Current recommendations for preterm infants advise catch-up growth in the first weeks of life and are based upon fetal nutrition and growth rates (4, 5). Catch-up growth is defined as weight and length gain greater than the intrauterine growth rate for the gestational age of the preterm infant. One way medical professionals achieve these goals is by increasing the caloric intake for the infants using supplementation of breast milk or specialized formula. Human development is complex and is affected by many variables including genetics, environment and nutrition. Nevertheless, inadequate postnatal growth is often seen in the neonatal intensive care unit (NICU) and may be caused by a variety of reasons. Specifically, preterm infants may develop chronic illnesses and require a positive energy balance to maintain vital functions (6). Overall, adequately nourishing and promoting proper growth in preterm infants is a challenge in the NICU environment (5).

Rapid fat deposition and complete development of major organ systems occurs in the third trimester of pregnancy. Premature infants are at risk for altered body fat composition and distribution due to an incomplete third trimester. Studies show that preterm infants at term-corrected age have higher amounts of total body and/or abdominal fat, as compared to term infants (7, 8). Research is needed to assess whether the increased body adiposity is due to an adaptation to the extrauterine environment and/or a combination of other causes. Interestingly, some investigations show that the catch-up growth, necessary for preterm infant brain development, has deleterious consequences for metabolic and cardiovascular health (4). Increased infant fat deposition may also be associated with a higher risk for developing conditions such as metabolic syndrome, obesity and diabetes mellitus in later life (9). Therefore, precise determination of body composition in premature infants may aid health professionals in selecting appropriate interventions to ensure proper postnatal growth.

Valid methods of assessing growth and body composition in infants include anthropometric measurements, such as body weight, length and head circumference, skinfolds, magnetic resonance imaging (MRI), dual energy x-ray absorptiometry (DXA), and air displacement plethysmography (ADP). Anthropometric methods are commonly used in a clinical setting due to low cost and ease of measurement (10) while MRI is not routinely used to assess preterm infants due to high cost and limited availability. Currently, DXA is the 'gold standard' for body composition measurement. However, DXA is rarely used in a clinical setting to assess infant growth due to high cost, radiation exposure, and limited availability in hospitals (11). ADP has recently been validated in infants by comparing the accuracy with use of deuterium dilution (4). The infant ADP system (PEA POD®, LMI, Concord, CA) calculates body fat percentage (%BF) by direct measurement of subject mass and volume. Advantages of using ADP with infants include lack of radiation exposure, portability, precise measurements, and training for ease of use. Therefore, ADP has the potential to be a safe, convenient and accurate method for determining body composition in infants.

Significance of Problem

Currently, premature births account for approximately 12% of live deliveries in the United States (3). The Barker Hypothesis states that reduced or incomplete fetal growth is associated with chronic diseases later in life, such as cardiovascular and metabolic disease (12, 13). Many research studies show adverse effects from a premature birth and reduced fetal growth. For example, Mattia et al. (1998) indicate that neurodevelopmental conditions associated with prolonged physiologic instability in preterm infants, independent of gestational age (14). In addition, animal models imply that early growth restriction of offspring is related to future development of metabolic syndrome, diabetes and renal failure (9).

The American Academy of Pediatrics recommends that a preterm infant's body composition mimics in utero body composition and growth rates until term age. Roggero and colleagues (2009) state that this recommendation of body composition, specifically concerning fat mass, is not achieved postnatally in preterm infants (6). The study reports a significantly higher percentage of fat mass in preterm infants at term-corrected age compared to term infants. Additionally, Uthaya et al. (2005) document that preterm infants at term-corrected age have increased intraabdominal adipose tissue, as compared to term infants. Uthaya also explains that after rapid postnatal growth, preterm infants have increased total and subcutaneous adipose tissue (8). Lastly, Cooke et al. (1999) observe altered fat and lean mass in premature infants using DXA. The premature infants at term-corrected age have higher body fat percentages and lower lean masses compared with term-born infants (15).

There are several theories regarding why preterm infants have more body fat than term infants. These speculations include notions based on fat deposition related to illness, stress after birth, or excessive calories administered by the health care team to ensure catch-up growth (16, 17). For example, stress from routine care of premature infants is related to increased levels of cortisol which promotes total body/abdominal fat deposition (16, 17). Despite many proposed theories, few studies examine interventions to promote increased lean mass and less fat mass in preterm infants. Of these, one intervention demonstrates that a proper ratio of protein to total energy in human milk feeds may ensure appropriate infant body composition (5).

Infant body composition measurements provide insight on growth patterns, diet adequacy, and efficacy of medical interventions (6). Body composition methods may be used more frequently in future research and diagnosis to monitor and prevent poor growth in infants. Thus, studies that evaluate a variety of body composition techniques are needed. Few studies have examined the efficacy of body composition measurement methods in infants. Koo et al. (2004) show that derived anthropometric measurements (weight, length, arm/thigh muscle area, arm/thigh fat area and head, chest, abdomen, mid-arm and mid-thigh circumferences) are comparable to DXA in neonates; however, the predictability may be different in infants with altered in utero growth (11). Ellis et al. (2007) confirm a consistent accuracy and reliability of the ADP system compared with a four-compartment model (measurements of total body water, bone mineral content and total body potassium) in infants (18). However, the accuracy of ADP for determining fat mass postnatally in preterm infants is unclear even though the system is the preferred infant body composition measurement method.

More studies are needed to document dissimilarity in body composition between preterm and term infants. In many studies, a comparison between anthropometry, skinfolds and percent body fat is unclear. Identifying these physiological differences will provide basis for appropriate care methods for the preterm infant. Also, low-risk methods of accurately determining body composition are necessary to assess infant growth and nutritional status.

Purpose/Hypotheses of Research

The purpose of the study is to improve the understanding of the differences in fat distribution in premature and term infants and to compare infant body composition methods.

We hypothesized that: 1) body fat deposition will be greater in prematurely born infants compared to infants born at term; and 2) percent body fat by ADP will correlate positively with mid-arm, mid-thigh, subscapular skinfold thickness, and derived anthropometry (body mass index).

The data for this analysis are a subset of data from the PREMA study. The specific aims of the study are:

1. To compare body fat deposition of premature infants, born between 32 to 36 weeks postmenstrual age (PMA), when they achieve 'term' corrected age (38 to 40 weeks PMA) to term-born infants using ADP.
2. To compare the relationships between fat deposition measured by ADP, derived and measured anthropometry and skinfold thickness in medically stable, late gestation preterm infants and term-born infants.

METHODS

Research Design

This research was a comparative study in which premature infant body composition at term-corrected age and full term infant body composition at discharge were examined. Also, the relationships between fat deposition measured by ADP, measured and derived anthropometry, and skinfolds, in medically stable, late gestation preterm infants and term-born infants were assessed.

ADP was used to measure body composition. Also, assessments of body weight, length, head circumference, abdominal circumference, mid-arm circumference, mid-thigh circumference, and bicep, tricep, subscapular and suprailiac skinfolds were conducted. Infant birth weight, length and head circumference were pulled from the infant's electronic medical record in PowerChart® (Cerner, Kansas City, MO). Maternal medical history was obtained via questionnaire (Appendix). The University of Utah Institutional Review Board for Human Subjects approved the study protocol.

Subject Selection Criteria

Premature infants (n = 28) admitted to the University of Utah Hospital NICU and born between 31 4/7 and 35 3/7 weeks gestation by maternal dates, mid-pregnancy fetal ultrasound, and physical exam at birth and with birth weight, length, and head circumference between the 1st to 90th percentiles (NCHS growth curve) for gestational age were eligible for the study. Full term infants (n = 28), 37 4/7 to 41 3/7 weeks gestation by maternal dates, mid-pregnancy fetal ultrasound, and physical exam at birth who were admitted to the University of Utah Hospital well baby nursery and whose birth weight, length, and head circumference between the 1st to 90th percentiles (NCHS growth curve) for gestational age were eligible for the study as part of the full term reference.

At the time of informed parental consent, infants were stratified by gestational age (31 4/7-32 3/7; 33 4/7-34 3/7; 34 4/7-35 3/7; full term), gender (male, female), birth weight category (Small for Gestational Age [SGA], 1-5th percentile; Appropriate for Gestational Age [AGA], 5th-90th percentile), race (white, non-Hispanic versus Hispanic), and feeding (human milk versus premature infant formula). Exclusion criteria included postmenstrual age < 31 4/7 and > 35 3/7 weeks at birth for premature infants and <37 4/6 and >41 3/7 for full term reference infants, chromosomal abnormalities, major congenital anomalies, major surgery, severe CNS injury (asphyxia, congenital hydrocephalus), inborn errors of metabolism, assisted ventilation or inability to start enteral feedings by 96 hours of age, or any other condition known to interfere with delivery of enteral feedings or postnatal growth.

Infants were screened for study eligibility within 24 hours of delivery. Hillarie Slater, CPNR's Research Coordinator, identified infants that met inclusion criteria and parents were then asked about their interest in the study. Written, informed consent was obtained from one or both parents of the child after the parents had read the parental permission form and all questions had been answered. After a copy of the signed consent form was given to one or both parents, measurements were taken before the newborn was discharged from the hospital. Preterm infant physical measurements were completed within 72-96 hours of birth and weekly thereafter until hospital discharge or term gestation (38 weeks PMA). Full term reference infants were measured within 24-72 hours of birth.

Subjects were compensated with a $10 gift card for each measurement session. The total number of measurement sessions ranged between one to six sessions for preterm infants and one measurement for full term reference infants. Therefore, total compensation ranged between $10 and $60.

Data Collection

Anthropometrics and Skinfolds

Body weight was measured to the nearest 1 gm with infants in a clean diaper during a quiet state using a digital electronic bed scale. Length was measured to the nearest 0.1 cm using an infant length board. Head circumference was measured at the largest occipitofrontal circumference using a vinyl coated fiberglass retractable tape measure to the nearest 0.1 cm. Mid-arm, mid-thigh and abdominal circumferences were measured using the same vinyl coated fiberglass tape used to measure the child's head. Abdominal circumference was measured immediately above the infant's umbilicus with the infant lying supine during quiet respiration. Mid-arm circumference was taken on the left side of the child's body, with the child lying on his/her right side. Mid-thigh circumference was measured on the left limb with child lying in the supine position. Length, head circumference, abdominal circumference, mid-arm circumference and mid thigh circumference were done in triplicate until values fell within 0.3 cm of one another. The final value was the average of the three measurements. Tricep, bicep, subscapular and suprailiac skinfold thicknesses were measured in triplicate using Lange skinfold calipers (19).

Air Displacement Plethysmography (ADP)

Body composition by air displacement plethysmography (ADP) was obtained with a PEA POD (Life Measurements Inc., Concord, CA). ADP utilizes the inverse relationship between volume and pressure in two enclosed chambers to determine whole body density. A two-compartment model then uses whole body density to calculate fat and fat-free mass percentages. The infant was placed in the PEA POD measurement tray and slid into the measurement compartment. A clear Plexiglas window kept the infant in constant visual range of study personnel during the measurement period. The measurement chamber door was closed. Automatic volume calibration began while subject biographical information was inputted into the software. After the first calibration had concluded, the infants mass (weight) and body volume were measured. A second automatic calibration followed, after which fat and fat-free percentage results were tabulated by the software and displayed on the monitor. Test results were printed, entered into the master data files, and stored in the patient's study binder.

Dietary Intake and Medications

The 24-hour intake and output and medication information was retrieved from the PowerChart® medical records and recorded into the infant's study binder each day. Dietary intake data included source (IV and/or enteral), type (dextrose solution, human milk, or commercial formula), and fluid volume. Medication use was tracked to identify exposure to medications that may impact postnatal growth (caffeine and vitamin/mineral supplements).

Maternal History Questionnaire

The maternal history questionnaire assessed factors known to be associated with the outcome of a pregnancy. The questionnaire included items concerning ethnicity; maternal birth weight, education level, pre-pregnancy weight, pre-delivery weight; paternal age, weight, height; and past pregnancies. Additional items addressed current medical conditions, medications taken during pregnancy and soy products consumed. Lastly, the amount of physical activity prior to and during pregnancy was obtained.

Infant Clinical Status

The infant's bedside nurse provided information on the infant's clinical status and physiological stability prior to any study-related measurements or procedures. Questions included presence of acute illness or infection, temperature instability, apnea and bradycardia episodes, supplemental oxygen requirement, evidence of enteral feeding intolerance, and anemia. The attending physician or assigned neonatal nurse practitioner was consulted if physiological stability was questionable and measurement session was delayed up to 48 hours.

Statistical Methods, Data Analysis and Interpretation

The hypothesis that body fat deposition will be greater in prematurely born infants compared to infants born at term (4.0 ± 2.0%) was tested by ANOVA with gender, race, age, and feeding treated as potential confounding variables. The hypothesis that %BF by ADP will correlate positively with derived anthropometry (body mass index, BMI, body weight/length^2) was tested by Spearman correlation with a $R \geq 0.70$ considered significant. Potential confounders and effect measure modifiers for those associations were evaluated and added to the analyses by multivariate analyses of variance (MANOVA) and/or multiple linear regression modeling. Statistical analyses were performed using SPSS (SPSS, Version 20, SPSS Inc., Chicago, IL) and significance was set as $p < 0.05$.

RESULTS

Table 1 describes maternal characteristics of preterm and term infants. There were no statistically significant differences between the groups. For both cohorts, the mothers' age, pre-pregnancy BMI and total pregnancy weight gain showed a wide range. Regarding pre-pregnancy BMI, 35.7% (n = 10) of the preterm mothers and 35.7% term (n = 10) mothers were classified as overweight or obese (BMI $\geq$ 25). Also, the majority of the mothers for both preterm and term infants reported taking prenatal vitamins during their pregnancy (80%, n = 45). Lastly, mothers of both cohorts reported similar levels of physical activity before and during pregnancy. Additional maternal history and infant feeding results of this study will be described in an article by Daly-Wolfe et al.

Table 1. Characteristics of mothers of preterm and term infants.[1,2]

Variable	Preterm infants	Term infants
Maternal age (years)	29.08 ± 6.67	30.19 ± 5.53
Pre-pregnancy body mass index (kg/m^2)	25.53 ± 6.76	24.13 ± 5.15
Total pregnancy weight gain (kg)	17.85 ± 14.94	12.31 ± 4.86
Number of mothers that took prenatal vitamins	22 (78.6%)	23 (82.1%)
Physical activity before pregnancy (days per week)	2.19 ± 2.09	2.92 ± 1.87
Physical activity during pregnancy (days per week)	1.27 ± 1.82	1.81 ± 1.63

[1]All values are means ± SDs unless otherwise noted.
[2]No significant differences were found. $p > 0.05$

Table 2 depicts demographic information for the preterm and term cohorts at baseline and hospital discharge. Males represented slightly less than half the sample population in both preterm and term infant cohorts. Birth gestation was 33.45 weeks (SD = 0.97) for preterm infants and 39.35 weeks (SD = 0.84) for term infants. Additionally, the majority of total infants were non-Hispanic white (75.0%, n = 42). All preterm infants and 96.4% (n = 27) of the term infants were born AGA. The number of weekly measurements for preterm infants ranged from one to six measurements with an average of 3.36 (SD = 1.52) sessions. Within the first week of life, 92.9% (n = 26) of preterm infants received a combination of parenteral and enteral nutrition. At discharge, 42.9% (n = 12) of preterm infants exclusively received breastmilk or fortified breastmilk. Of the term infants, 92.9% (n = 26) were exclusively breastfeeding. During the hospital stay, 42.9% (n = 12) of preterm infants received a multi-vitamin and 7.1% (n = 2) received at least one caffeine dose. At discharge, preterm infant corrected gestational age, body weight, length, and body circumferences were significantly lower than term infants ($p < 0.01$). Also, preterm infant BMI (M = 11.43 kg/m^2, SD = 1.13 kg/m^2) was significantly lower than term infants (M = 12.72 kg/m^2, SD = 0.91 kg/m^2, $p < 0.001$).

Table 3 represents tricep, subscapular, bicep and suprailiac skinfold measurements for preterm and term infants at discharge. There were no significant differences in skinfold thickness between the two groups on any of the body sites ($p > 0.33$). The smaller sample size of preterm infants with skinfold measurements was due to the addition of skinfold measurements in the study protocol midway through obtaining data on preterm infants.

To test the hypothesis that preterm infants would have significantly higher body

Table 2. Characteristics of preterm and term infants at baseline measurement and hospital discharge.[1]

Variable	Preterm Infants	Term Infants
N	28	28
Number of male subjects	13 (46.4%)	12 (42.9%)
Gestation at birth (PMA weeks)	33.45 ± 0.97*	39.35 ± 0.84
Number of non-Hispanic white	19 (67.9%)	23 (82.1%)
Number of Hispanic	9 (32.1%)	5 (17.9%)
At first measurement:		
Gestational age (PMA weeks)	33.99 ± 0.98	
Weight (g)	1871.5 ± 311.1	
Length (cm)	43.57 ± 2.08	
Head circumference (cm)	30.43 ± 1.41	
Mid-arm circumference (cm)	7.92 ± 0.77	
Mid-thigh circumference (cm)	11.01 ± 1.18	
Abdominal circumference (cm)	24.96 ± 2.03	
At hospital discharge:		
Gestational age (PMA weeks)	36.18 ± 1.31*	39.35 ± 0.84
Weight (g)	2382.2 ± 408.6*	3098.1 ± 373.8
Length (cm)	45.58 ± 2.09*	49.27 ± 1.91
Head circumference (cm)	32.34 ± 1.60*	34.29 ± 1.17
Mid-arm circumference (cm)	8.85 ± 0.77*	11.05 ± 1.18
Mid-thigh circumference (cm)	12.88 ± 1.39*	14.74 ± 1.67
Abdominal circumference (cm)	28.11 ± 2.67*	30.77 ± 2.37

[1]All values are means ± SDs unless otherwise noted. *Significantly different from term infants, $p < 0.01$.

Table 3. Skinfold measurements at discharge in preterm and term infants.[1, 2]

Variable	Preterm infants	Term infants
Number of infants	10	28
Tricep skinfold (mm)	3.06 ± 0.79	3.25 ± 0.59
Number of infants	10	28
Subscapular skinfold (mm)	3.64 ± 0.97	3.38 ± 0.61
Number of infants	9	26
Bicep skinfold (mm)	2.76 ± 0.64	2.65 ± 0.61
Number of infants	8	25
Suprailiac skinfold (mm)	2.58 ± 0.89	2.41 ± 0.60

[1]All values are means ± SDs unless otherwise noted.
[2]No significant differences were found. p > 0.33

fat compared to term infants, two-tailed independent samples *t*-tests were conducted on percent body fat measurements by ADP at discharge measurements. Preterm infant percent body fat (*M* = 11.91%, SD = 4.47%) was higher than term infants (*M* = 9.64%, SD = 4.01%) at discharge, which approached significance (p = 0.057). Figure 1 illustrates that preterm infant percent body fat trended upwards linearly ($R^2 = 0.93$) as their age approached term-corrected age.

Spearman correlations were used to test the hypothesis that percent body fat by ADP would show positive relationships with mid-arm, mid-thigh, subscapular skinfold thickness, and derived anthropometry (body mass index). The results of this analysis are presented in Table 4, with the significant positive correlations indicated. In preterm infants, tricep, bicep and suprailiac skinfolds strongly correlated to percent body fat ($r > 0.7$, $p < 0.01$) and circumferences and subscapular skinfolds moderately associated with percent body fat ($0.5 < r > 0.7$, $p < 0.005$). In term infants, circumferences and tricep, subscapular and suprailiac skinfolds moderately correlated with percent body fat

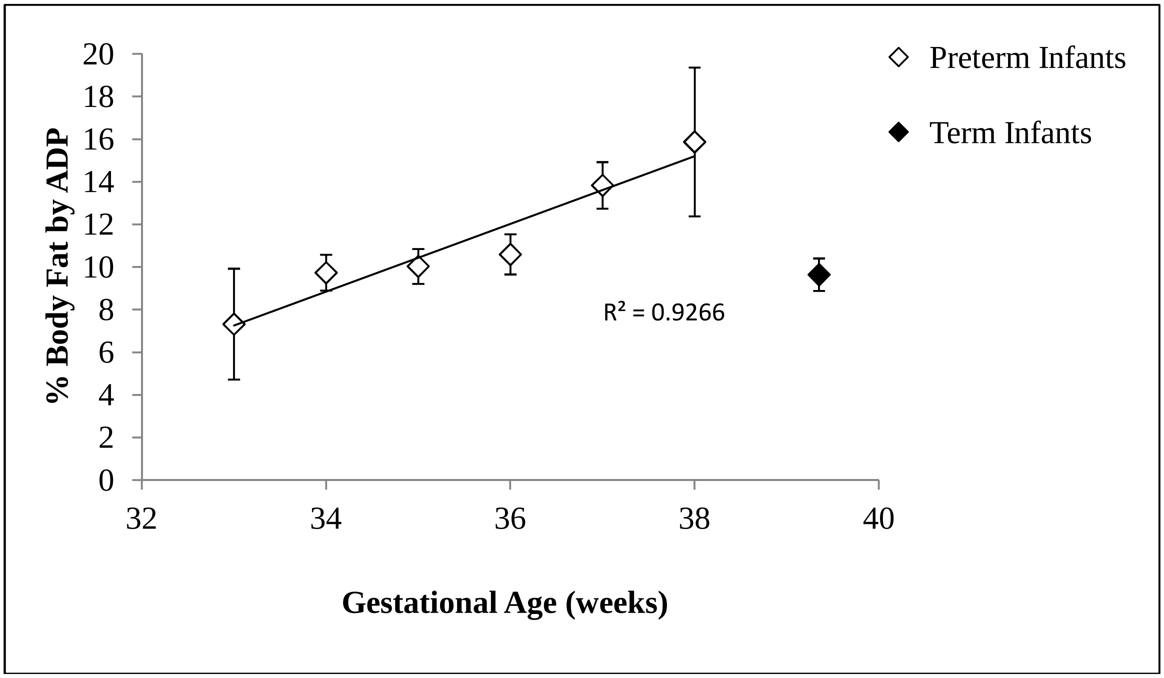

Figure 1. Percent body fat of preterm infants over adjusted gestational age compared to term infants.

Table 4. Correlations of percent body fat by ADP, anthropometric measurements and skinfolds.

	Percent Body Fat Preterm infants	Percent Body Fat Term infants
Mid-arm circumference (cm)	0.52*	0.67*
Mid-thigh circumference (cm)	0.61*	0.61*
Abdominal circumference (cm)	0.52*	0.54*
Tricep skinfold (mm)	0.72*	0.40**
Subscapular skinfold (mm)	0.69*	0.54*
Bicep skinfold (mm)	0.78*	NS[1]
Suprailiac skinfold (mm)	0.88*	0.57*

[1]NS, not significant. *p < 0.01, **p < 0.05

(r > 0.40, p < 0.05). There was no significant relationship between bicep skinfold thickness and percent body fat in term infants. In addition, BMI moderately correlated with percent body fat in preterm infants (r = 0.55, p < 0.001) and strongly correlated in term infants (r = 0.71 p < 0.001).

Furthermore, a stepwise linear regression was conducted to compare anthropometric measurements and skinfolds to percent body fat by ADP in the sample of preterm and term infants. Central fat skinfolds (average of subscapular and suprailiac skinfold) was the only significant predictor of percent body fat in both preterm and term infants (R^2 = 0.492, p < 0.001). In preterm infants alone, central fat skinfold thicknesses predicted 61.7% of the variability of percent body fat by ADP (p = 0.002). In addition, mid-arm circumference may be a good predictor of body fat percentage in preterm infants because it represented 67.4% of the variance of the ADP system (p = 0.002). On the contrary, the average of mid-arm and mid-thigh circumference predicted 62.9% of the variability of percent body fat by ADP (p < 0.001) in term infants.

Lastly, at baseline, length and head circumference for preterm males were significantly larger than preterm females despite gestational age not being significantly different ($p < 0.05$). No gender differences were seen at discharge in gestational age, body weight, length, body circumferences, skinfolds and percent body fat by ADP in term and preterm infants.

DISCUSSION

Preterm infants are at risk for aberrations in adiposity due to incompletion of the third trimester of pregnancy, unaccustomed extrauterine needs and nourishment that is different than that of a fetus (6, 8). The first weeks of life for preterm infants are a critical period of development that set the stage for future quality of life, metabolism, and growth (20). Our study detects differences in body composition between preterm and term infants and determines relationships between body fat percentage measured by ADP and anthropometry/skinfolds. Overall, the study results support previous research that preterm infants near or at term-corrected age have a percent body fat higher than infants born term (6, 7, 8, 15). Specifically, our findings indicate that anthropometry and ADP, but not skinfolds, detect significant differences in body composition between preterm infants and term infants at hospital discharge. The data seem to suggest a linear rate of body fat deposition in preterm infants. However, future research is needed to confirm results and document the complete trend of percent body fat in preterm infants after catch-up growth has been achieved.

Furthermore, our data show that BMI values are lower in preterm infants at discharge compared to term infants, even though their body fat percentage is higher. Premature infant weight gain, rather than BMI, is used as a primary indicator of nutritional status in the NICU. According to the Centers for Disease Control and

Prevention, BMI is used to predict body fatness and screen for obesity in children 2 years and older (21). Therefore, BMI may be unreliable in the population of preterm infants as an indicator of body composition, yet is recommended in a clinical setting for children 2 years and older. Anthropometric measurements and skinfolds could be used in place of BMI to indicate body fatness since there is a correlation to percent body fat measured by ADP. Studies with larger sample sizes are needed to create norms and equate the relationship between anthropometry, skinfolds and body fat percentage.

Regarding skinfolds, our data reveal no significant differences in tricep, subscapular, bicep, or suprailiac skinfold thicknesses between preterm and term infants at hospital discharge. Skinfold thickness is a measurement solely of subcutaneous fat deposition. Increased abdominal visceral adipose tissue is known to be correlated with hypertension and glucose intolerance, independent of obesity (22). Fat deposition may be mainly occurring viscerally in preterm infants since our data show an increased body fat percentage, yet no difference in subcutaneous fat measured by skinfolds.

Specifically with preterm infants, mid-arm circumference may be used to predict body fat percentage in a clinical setting when the ADP system is not available. Our small sample size (n = 10) of preterm infants with skinfolds limits our ability to reliably correlate subscapular and suprailiac skinfolds to body composition. Further investigations are needed before skinfolds can be used to predict body fat. With term infants, the use of both mid-arm and mid-thigh circumference leads to a better estimate of body fat percentage than one measurement alone. While body weight is recommended as a growth assessment tool in preterm infants, coordination with body composition methodology may provide a better analysis of growth quality. Differences in fat deposition between preterm and term infants imply that techniques to measure body composition should be considered tools needed to properly assess infant growth status.

Our results seem to indicate that gender does not play a role in body fat deposition. Overall, the research is controversial regarding gender differences in infant body composition. Some studies indicate that males have higher body fat compared to females (19, 23) or that there are no gender differences in body fat percentage or mass (6, 24). However, these studies vary in gestational age, body weight and body composition methodology (6, 19, 23, 24). Additionally, females typically have higher fat mass compared to males of the same age. This observation can be seen as early as the first few months of life (19). Thus, further investigation is needed regarding the association between gender and preterm fat deposition.

This preliminary study indicates areas of further investigation in understanding abnormal body fat deposition and improving growth quality of preterm infants. Our research provides a foundation to test interventions designed to modulate fat deposition, and in turn, improve growth quality of hospitalized, preterm infants. Overall, the study supports the hypothesis that preterm infants develop an increased rate of body fat deposition as they approach term-corrected age, which can be monitored by anthropometry or ADP.

Strengths and Weaknesses

A major strength of the study is the use of multiple body composition measurement techniques that are validated in infants. The use of numerous techniques improves upon the validity of the data collected. Another strength of the study is the research design, as key confounding variables that affect postnatal growth are examined, such as maternal history and gender. Lastly, the study provides reference data for future neonatal studies.

A major study limitation is the small sample size. Using G*Power 3.1.3, a sample size of 40 would be needed to achieve a power of 80%, to obtain moderate correlation factors and to detect a moderate effect size of 0.35. The sample size was dependent on the number of infants born prematurely who were admitted to the University Hospital Neonatal Intensive Care Unit or Well-Baby Nursery. Recruitment success of those infants admitted to the hospital further limited sample size. In addition, a few infants were excluded from the study; however, a total of 36 preterm infants and 35 term infants had at least one measurement completed. This exclusion was due to inability to obtain percent body fat by ADP due to complications with the PeaPod machine or inability to participate in the measurement with certain oxygen requirements.

Another limitation is that participants were restricted to infants admitted to the University Hospital in Salt Lake City, UT. Therefore, the study population may not reflect the diversity of neonates in the United States. Also, the study only follows medically stable preterm infants from birth to discharge. Preterm infants are often discharged before reaching term-corrected gestational age as long as they meet certain criteria, particularly concerning respiration and nutritional intake. In addition, the results may not apply to other preterm infants born with certain severe health conditions. Lastly, limitations were inherent in some of the measurement techniques. For example, the ADP encountered technical difficulties if an infant became agitated during the measurement process.

Potential Applications of Research

The United States has one of the highest rates of preterm births in the world, with over half a million babies born prematurely every year (25). Studies report many short and long-term consequences of prematurity (3). Medical professionals are becoming more concerned with nutritional status in infants due to recent research with regards to the relationship of growth and possible cause of metabolic disturbances in later life.

The study emphasizes the importance of designing appropriate intervention methods for a preterm infant to avoid aberrations in body fat composition. Also, the study provides a comparison between standard body composition measurement techniques performed on preterm and term infants. Thus, data from this study may be used to strengthen future neonate studies that involve infant body composition and contribute to the expanding pediatric research concerning the long-term consequences of altered infant body fat distribution. Overall, the study provides insight on measuring infant body composition in a clinical setting and the differences in adiposity between preterm and term infants.

Conclusion

In summary, preterm infant percent body fat is higher as they approach term-corrected age than percent body fat in newborn term infants. This finding supports the connection between a preterm birth and increased risk of metabolic imbalance, including glucose intolerance, in preterm children and young adults. In addition, the study results reveal a correlation between anthropometric and skinfold measurements with percent body fat by ADP. Future research is needed to understand variables that affect infant body fat deposition and to determine reliable, low-risk and cost-effective ways of measuring and monitoring infant body composition.

APPENDIX: MATERNAL HISTORY QUESIONNAIRE

Contact Information:

Name: ____________________________ Date: _____________________

Address: ____________________________ Date of Birth: _____________________

____________________________ Home Phone: _____________________

Best Time to Reach You: _________________ Second Phone: _____________________

E-mail address (if available): ____

Personal Information:

Maternal
Ethnicity: ❑ White ❑ Hispanic ❑ Asian ❑ Black
❑ Native American ❑ Pacific Islander ❑Other:_________________

Baby's
Ethnicity: ❑ White ❑ Hispanic ❑ Asian ❑ Black
❑ Native American ❑ Pacific Islander ❑Other:_________________

What was your birth weight? _________________

What is your education level?

❑ High school/GED ❑ Some college/technical school
❑ Associate's degree ❑ Bachelor's degree
❑ Post-Graduate degree ❑ Other: _________________________

What was your pre-pregnancy weight? ___________ Height? ____________

What was your pre-delivery weight? _____________

Please provide the following information in relation to the baby's *father*:

Age: _______ Weight: _______ Height: _______

Pregnancy Information:

How many children do you have (not counting this pregnancy)? ___________

How many pregnancies have you had (not counting this pregnancy)? _________

Have you done any of the following during your current pregnancy?

❑ Smoke ❑ Consume Alcohol
❑ Used Recreational Drugs ❑ Used Over-the-Counter or Prescription Medications
❑ Taken Prenatal Vitamins
❑ Consumed Soy Products (i.e. soy milk, soy flour, soy protein, tofu, tempeh, miso soy burgers/sausage, soy yogurt/cheese, etc.)

If you have consumed soy products during your pregnancy, please complete the table below:

Soy Product Consumed	***Circle which trimester***	***Servings per week?***	***Servings per day?***
	1 2 3		
	1 2 3		
	1 2 3		

Do you have any medical conditions, either diagnosed prior or subsequent to this pregnancy?
No **Yes** If yes, please specify: ____
____
If you have used over-the-counter or prescription medications during your pregnancy, please complete the table below.

Medication	***Reason for Use***	***Dose***	***Start Date***	***Duration of Use***

Physical Activity Information:

How many days towards the end of your pregnancy (on average per week) did you perform physical activity where your heart beats faster and your breathing is harder than normal for 30 minutes or more? (can be 30 minutes in a row or 3, 10 minute blocks)

0 days 1 day 2 days 3 days 4 days 5 days 6 days 7 days

How many days in a typical week did you perform activity such as this?

0 days 1 day 2 days 3 days 4 days 5 days 6 days 7 days

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