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Age of Achievement of Gross Motor Milestones in Infancy and Adiposity at Age 3 Years

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Abstract

Early life physical activity may help prevent obesity but is difficult to measure. The purpose of this study was to examine associations of age of achievement of gross motor milestones in infancy with adiposity at age 3 years. Seven forty one mother/infant dyads participated in a longitudinal study in Massachusetts. Exposures were age of attainment of 4 gross motor milestones—rolling over, sitting up, crawling, and walking. Outcomes were 3-year sum of subscapular and triceps skinfold thickness (SS + TR) for overall adiposity, their ratio (SS:TR) for central adiposity, and body mass index (BMI) z-score. We used linear regression models adjusted for confounders to examine motor milestone achievement and later adiposity. Rolling over (0.04, 95% CI: 0.008, 0.07) and sitting up (0.02, 95% CI: 0.001, 0.05) at 6 months were associated with increased SS:TR compared with attainment before 6 months. Walking at 15 months was associated with 0.98 mm higher SS + TR (95% CI: 0.05, 1.91) compared with walking before 12 months. Age at crawling was not associated with the outcomes. None of the milestones were associated with BMI z-score. Age of motor milestone achievement was only a modest predictor of adiposity. Later rolling over and sitting up were associated with greater central adiposity, and later age at walking was associated with greater overall adiposity at age 3 years. Although we controlled for birth weight and 6-month weight-for-length in our models, more detailed assessment of early adiposity prior to achievement of motor milestones is needed to help determine causality.

Keywords

Infant; Motor development; Obesity; Physical activity

Introduction

The achievement of gross motor milestones in infancy is fairly universal, although age of attainment is influenced by both biology and the environment. Based on data from five

countries, the World Health Organization (WHO) developed normal age ranges for achievement of motor milestones among healthy children [1]. Pediatric health care providers may use these standards to flag children at risk for developmental delays or help identify late achievers. Predictors of later attainment of motor milestones include earlier gestational age [2, 3], disease or disability status [4–6], twin status [7–9], insufficient dietary and nutrient intake [6, 10–12], supine sleep position [13–15], a poor home environment [16–18], and low socio-economic status [17]. Although the WHO outlined a range of ages for normal attainment of motor milestones, earlier achievement may be associated with some beneficial outcomes. Previous research suggests that younger age at attainment positively predicts cognitive outcomes in adulthood such as educational attainment [19], executive function [20], and level of intelligence [21]. Little is known, however, about the relationship between earlier motor milestone achievement and other health outcomes such as obesity.

Recent evidence suggests that excessive weight gain during infancy may lead to both obesity [22–24] and recurrent wheezing [25] later in childhood, but the causes of rapid weight gain in infancy are not well understood. Researchers have examined associations of both energy intake and energy expenditure and adiposity and found that both play a role in the development of obesity in infancy [26–29]. Recommendations for physical activity in infancy are scarce, and even defining physical activity for infants is challenging; researchers are just beginning to examine the importance of early movement experiences. Infants are conditioned from birth to move in various ways such as kicking, rocking on hands and knees, and pushing up on arms; these skills are practice for later, more advanced movement skills [30]. However, being confined for long periods of time may affect motor skills [30]. Moreover, a recent study found that nearly two-thirds of toddlers sampled watched an average of 75 min of television per day. A second study found that infants may spend up to 60 h a week in restrictive devices such as high chairs, car seats (even when not in the car), bouncy seats, and strollers [30]. With adequate supervision and attention to safety, infants should be allowed to move freely and explore their surroundings. Physical activity allows infants to build muscle, which may facilitate achievement of gross motor milestones [31]. Physical activity and gross motor movement also provide opportunities for infants to expend energy [29, 32, 33]. Providing opportunities for infant movement such as creeping, crawling, cruising, and walking, may be the most effective way to increase energy expenditure in very young children.

Although evidence is limited, physical activity in infancy may help control excessive weight gain and may help infants maximize their developmental potential. Obesity has been linked to lower levels of fitness and motor skills in older children both cross-sectionally [34–38] and longitudinally [31, 39]. Obesity in infancy may delay achievement of gross motor milestones [31, 39, 40] and conversely, infants who attain motor milestones at later ages may be less physically active later in childhood [31]. These infants may prevent development of excess adiposity by building more muscle mass, expending more calories, and improving cardiovascular function. The purpose of this study was to examine the relationship between age of achievement of motor milestones in infancy and adiposity at age 3 years.

Methods

Population and Study Design

Infants were born to participants in Project Viva, a prospective cohort study of pregnant women and their offspring. We recruited women attending prenatal visits at one of 8 obstetric offices in a multi-site group practice located in eastern Massachusetts. To participate, women needed to speak English, be less than 22 weeks gestation at enrollment, and have a singleton pregnancy. Recruitment and retention protocols for this study are

published elsewhere [41]. We obtained informed consent and collected health history and demographic information from participants via questionnaires and interviews. All procedures were conducted in accordance with the ethical standards of the responsible committee on human experimentation and approved by the human subjects committee of Harvard Medical School and Harvard Pilgrim Health Care.

Main Exposures: Motor Milestones

Mothers reported their children's age of achievement of four motor milestones that are considered universal in child development and are relatively easy to evaluate: rolling over without assistance, sitting up without support, hands-and-knees crawling, and walking without assistance. Mothers reported age of achievement by month of each motor milestone on questionnaires (close-ended) when their infants were 6 months, 1 year, and 2 years of age. Previous studies have found maternal recall and report of their children's milestone achievement to be accurate [8, 19, 42], and this method of motor milestone assessment has been used in recent studies [43, 44].

Outcomes: 3-Year Adiposity

The adiposity outcomes of interest were the sum of subscapular and triceps skinfold thickness (SS + TR) for overall adiposity, their ratio (SS:TR) for central adiposity, and age- and sex-specific body mass index (BMI) z-score at 3 years of age. Trained Project Viva research assistants measured heights and weights using a calibrated stadiometer (Shorr Productions, Olney, MD) and scale (Seca model 881; Seca Corporation, Havover, MD), and they measured subscapular and triceps skinfold thicknesses with a Holtain caliper (Holtain Ltd., Crosswell, Crymych, Dyfed Wales, UK). We calculated age- and sex-specific child BMI z-scores using 2,000 Centers for Disease Control and Prevention reference data [45]. Project Viva data collectors adhered to standard measurement techniques [46] and participated in twice yearly anthropometric training.

Other Measures

Mothers reported their own height, pre-pregnancy weight, parity, smoking, education, and marital status; their household income; paternal height and weight; and child race/ethnicity and breastfeeding duration. We calculated gestational age from the last menstrual period or from a second trimester ultrasound if the two estimates differed by more than 10 days. We obtained birth weight from the clinical medical record and calculated birth weight for gestational age z-score [47]. Trained Project Viva data collectors measured weight and length for each infant at the 6-month study visit, from which we calculated weight-for-length z-score [45].

Data Analysis

We used separate multiple linear regression models to examine associations of age of achievement of each individual gross motor milestone, in categories, with each of the adiposity outcomes, as continuous variables. We first ran unadjusted analyses examining the relationship between individual motor milestones and each adiposity outcome. Next, in multivariable models, we included only those covariates that were of a priori interest. The final multivariable models included maternal pre-pregnancy BMI, parity (0, 1, 2+), maternal smoking (never, former, during pregnancy), maternal education (<college degree, college degree), marital status (married or living with partner, single); paternal BMI; yearly household income (<\$70,000, >\$70,000); child age, sex, race/ethnicity (black, white, Hispanic/Latino(a), other), birth weight for gestational age z-score, 6-month weight-for-length z-score, and breastfeeding duration. The multivariable models for SS:TR also included child's 3-year BMI z-score as a covariate to isolate the role of central adiposity. For

each milestone we used the earliest age category of achievement as the reference group. We conducted all analyses using SAS 9.1 (SAS Institute, Cary, NC).

Results

Participant Characteristics

The mean age (SD) of participants at the 3-year visit was 38.8 (3.2) months; 51.0% were female; 73.0% were white (Table 1). Reflective of a generally employed and insured managed care population, few women had less than a high school education or had annual household incomes below \$40,000. We collapsed groups with less than 25 infants, resulting in the following categories based on WHO windows for motor milestone achievement: <6 or 6 months for rolling over and sitting up; <6, 6–8, or 9 months for crawling; and <12, 12–14, and 15 months for walking. The ages at which infants achieved each motor milestone were similar to World Health Organization international averages [1]—81.5% rolled over before 6 months of age, 60.4% sat up after 6 months of age, 58.1% crawled between 6 and 8 months of age, and 44.6% walked between 12 and 14 months of age. Mean (SD) SS + TR was 16.7 (4.0) mm, SS:TR was 0.64 (0.16), and BMI z-score was 0.44 (1.03) units.

Of the 1,294 children who attended a study visit at age 3 years, we excluded 20 born prior to 34 weeks gestation and 533 with missing covariate, exposure, or outcome data, leaving 741 for the analysis. Comparison of the 741 participants in this analysis with the 533 participants who were excluded due to missing data showed a higher proportion of maternal white race (78% vs. 65%), college or graduate education (76% vs. 63%), and annual household income exceeding \$70,000 (68% v. 58%) but did not differ on mean gestational age at birth or offspring birth weight.

Multivariable Analysis

In the full multivariable model, rolling over (0.04, 95% CI: 0.01, 0.07) and sitting up (0.02, 95% CI: 0.001, 0.05) at 6 months of age or older were associated with increased SS:TR, compared with achieving these milestones before 6 months (Table 2). Walking at 15 months of age or older was associated with 0.98 mm higher SS + TR (95% CI: 0.05, 1.91) than walking before 12 months. Walking at 12–14 months was associated with an intermediate value, 0.42 mm (95% CI: −0.18, 1.43). Age at crawling was not strongly associated with any adiposity outcomes, and if anything, was associated with lower adiposity. For example, compared with crawling before 6 months of age, initiation of crawling between 6 and 8 months of age was associated with SS + TR of −1.25 mm (95% CI: −2.52, 0.01). However, crawling at >9 months was less strongly associated with SS + TR (−0.50 mm). None of the milestones was associated with BMI z-score at 3 years of age.

Discussion

Because gross motor activities such as crawling and walking expend energy, it is plausible that age of attainment of these milestones reflects habitual physical activity and regular movement during infancy. Therefore, it is possible that later attainment of these milestones could be a determinant of childhood obesity. In this study we found that later age at walking was associated with a modestly higher sum of skinfolds (overall adiposity) at 3 years of age but not with the skinfold ratio (central adiposity) or with BMI. While later walking probably reflects lower energy expenditure in the first 2 years of life, the magnitude of the association argues against using age at walking as a surrogate for physical activity in research studies. Age at crawling, which also expends energy, was not associated with any adiposity outcome and none of the outcomes were associated with BMI. It is possible that we did not find associations between motor milestone achievement and later BMI because BMI may be a

poor marker of adiposity in early childhood. Previous studies suggest that skinfold thickness is more closely associated with body fat than BMI in children [37–39, 41]. A recent study found that using BMI to assess fatness may be appropriate for heavier children but that differences in BMI in thinner children may be due to fat-free mass [38]. In a similar study, the authors suggest that BMI may be useful for screening children but was not recommended as a measure of overall adiposity [39].

We also found that later rolling over and sitting up were associated with greater central adiposity but not overall adiposity. Although we did adjust for birth weight and weight-for-length at 6 months of age, we did not measure skinfold thicknesses during infancy. Therefore, we could not examine the possibility of reverse causality: that already emerging central adiposity at age 6 months impedes rolling over or sitting up.

Another limitation of our study is the inclusion of English speaking women only and the relatively high family income and education level of study participants associated with families in Eastern Massachusetts, which may limit generalizability outside of this area. Also, although there is evidence that maternal report of motor milestones is valid [8, 19, 42], mothers in this study may not have stated their children's milestone achievement accurately. Mothers were not informed that they would be asked to report their children's gross motor milestones prior to enrollment in the study. This may have limited changes in behavior related to social desirability, but also may have decrease the accuracy of maternal self-report. In our study, however, we asked mothers to recall their children's motor milestone achievement at fairly regular intervals in an effort to improve the accuracy of reporting. A previous study assessing the validity of maternal report found that mothers were able to recall accurately their children's gross motor milestone attainment during infancy even after their children had reached 2 years of age [8].

Rates of obesity among children—even very young children—continue to rise. Nearly 10% of infants 0–23 months of age are considered obese [48, 49]. It is a public health priority to better understand determinants of excessive weight gain in early life. Many of the risk factors for obesity are modifiable, and early childhood may be a critical period for the prevention of excess adiposity. Efficacious and cost-effective interventions are needed to alter determinants of obesity in both clinical and public health settings [50]. However, additional information is needed to better understand and measure modifiable risk factors such as energy intake and energy expenditure.

Measuring physical activity in infancy is challenging. In two early studies, Rose et al. found that infant motor activity (assessed by trained observers) was more accurate than total caloric intake at predicting body size at 5 months of age [51, 52]. Our findings indicate that age of achievement of walking, while relatively easy to ascertain, was only a modest predictor of later adiposity. The need exists for more accurate measures of physical activity in infancy, although a recent study cautions against assessment with mechanical devices such as activity monitors [53]. It may be reasonable to measure inactivity in infants, such as time spent restricted in a crib, car seat, or stroller, as a marker for overall energy expenditure. Measures of both physical activity and inactivity are needed to assess the contribution of energy expenditure to development of adiposity in infants, and these measures should be feasible to use in large population studies.

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Table 1

Child and family characteristics of 741 participants from project viva

	Mean (SD)
Parent and Family Characteristics	
Maternal pre-pregnancy BMI, kg/m ²	24.4 (4.8)
Paternal BMI, kg/m ²	26.4 (3.8)
	% of Subjects
Maternal parity	
0	48.3
1	35.2
2	16.5
Maternal smoking	
Never smoker	71.1
Former smoker	19.8
Smoked during pregnancy	9.0
Maternal education	
<College degree	23.6
College or graduate degree	76.4
Household income	
\$70,000	31.7
>\$70,000	68.3
Child Characteristics	
Gestational age, wk	39.7 (1.5)
Birth weight for gestational age z-score	0.25 (0.94)
6-month weight-for-length z-score	0.73 (0.95)
Breastfeeding duration, m	6.6 (4.5)
Age at 3-year visit, m	38.8 (3.2)
Outcome measures at 3 years	
Skinfold thickness SS + TR, mm	16.7 (4.0)
Skinfold thickness SS:TR	0.64 (0.16)
BMI z-score	0.44 (1.03)
	% of Subjects
Developmental milestones	
Roll over <6 m	81.5
Roll over 6 m	18.5
Sit up <6 m	39.6
Sit up 6 m	60.4
Crawl <6 m	5.2
Crawl 6–8 m	58.1
Crawl 9 m	36.7
Walk <12 m	43.7
Walk 12–14 m	44.6

	Mean (SD)
Walk 15 m	11.6
Female	50.6
Child race/ethnicity	
Black	9.0
White	73.0
Hispanic/Latino(a)	3.2
Other	14.7

.SS subscapular, TR triceps, BMI body mass index

Table 2

Associations of age at attainment of motor milestones with adiposity at age 3 years among 741 participants from project viva

Motor milestone	Age achieved, m	SS + TR	SS:TR*	BMI z-score
Estimate (95% CI)				
Roll over	<6	0.00 (reference)	0.00 (reference)	0.00 (reference)
	6	0.50 (−0.22, 1.23)	0.04 (0.01, 0.07)	0.06 (−0.11, 0.22)
Sit up	<6	0.00 (reference)	0.00 (reference)	0.00 (reference)
	<6	0.24 (−0.34, 0.81)	0.02 (0.001, 0.05)	−0.03 (−0.16, 0.10)
Crawl	<6	0.00 (reference)	0.00 (reference)	0.00 (reference)
	8-Jun	−1.25 (−2.52, 0.01)	0.02 (−0.03, 0.07)	−0.27 (−0.55, 0.02)
	9	−0.50 (−1.79, 0.80)	0.03 (−0.02, 0.09)	−0.24 (−0.53, 0.05)
Walk	<12	0.00 (reference)	0.00 (reference)	0.00 (reference)
	14-Dec	0.42 (−0.18, 1.03)	−0.01 (−0.04, 0.01)	0.004 (−0.13, 0.14)
	15	0.98 (0.05, 1.91)	−0.003 (−0.04, 0.04)	−0.01 (−0.22, 0.20)

Models adjusted for child age, sex, race, birth weight for gestational age z-score, 6-month weigh-for-length z-score, and breastfeeding duration; maternal pre-pregnancy BMI, parity, smoking, education, and marital status; paternal BMI and household income

SS subscapular, TR triceps, BMI body mass index, CI confidence interval

* Additionally adjusted for BMI z-score