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ORIGINAL ARTICLE

Behavioral, Environmental, and Demographic Factors Associated with Objectively Measured Physical Activity in Infants

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Abstract

Background: To describe objectively measured physical activity (PA) in infants, and to identify demographic, behavioral, and environmental factors associated with infants' PA.

Methods: Participants were 6–7-month-old infants and their mothers ($N = 143$ dyads) from two Southeastern US counties. Infant measures included PA assessed by accelerometers at ankle and waist sites, motor developmental status (*i.e.*, stationary and locomotion), and anthropometric characteristics (*i.e.*, height and weight). Mothers provided information on home environment, child care settings, and family demographic factors. PA levels were compared across demographic subgroups. Correlation coefficients described associations between PA and continuous variables, including motor developmental status and anthropometric characteristics. Multiple linear regression analyses examined factors found to be independently associated with PA.

Results: Infants' PA counts were greater at the ankle (77,700 counts/hr) vs. the waist site (32,500 counts/hr). In univariate analyses, a diverse set of environmental, behavioral, and infant-level demographic factors were found to be significantly associated with PA at the ankle site. Multivariate analyses indicated that more advanced motor development status ($B = 666.3 \pm 329.8$, $p < 0.05$), attendance at home child care settings ($B = -13{,}724.4 \pm 5083.9$, $p < 0.05$), greater exposure to tummy time ($B = 213.5 \pm 79.9$, $p < 0.05$), and white racial/ethnic composition ($B = -19{,}953.4 \pm 5888.5$, $p < 0.01$) were independently, associated with infants' PA.

Conclusions: In 6–7-month-old infants, objectively measured PA was found to be associated with motor developmental status and physical and social environmental factors, including both demographic moderators and factors that are influenced by parents and caregivers. Longitudinal studies are needed to determine if these relationships persist or change as infants develop.

Keywords: accelerometry; child care; motor development; tummy time

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Introduction

Physical activity provides important health benefits to children and adolescents, and the body of knowledge linking physical activity (PA) to health in young people has developed rapidly in recent years. The 2008 PA Guidelines for Americans included PA recommendations for school-aged youth (6 to 18 years),[1] which were based on evidence demonstrating that PA has the potential to produce improvements in weight status, bone health, and cardiometabolic risk profile in that age group.[2] When updated in 2018, the PA Guidelines for Americans added recommendations for preschool-age children (3 to 5 years).[3] That action was based on evidence showing that PA provides important benefits to bone health and weight status in 3–5-year-old children.[4] However, to date, the US federal guidelines do not include recommendations for children younger than 3 years, because the relationship between PA and health is not well understood in that age group.

The World Health Organization (WHO) has adopted PA recommendations for school-age and preschool-age children that are similar to those included in the United States guidelines.[5] However, WHO has gone beyond the US guidelines by providing PA recommendations for infants (less than 1 year) and toddlers (1 to 2 years). The guidelines for infants recommend that they are ‘‘physically active several times a day in a variety of ways, particularly through interactive floor-based play.’’ Furthermore, they recommend that infants who are not yet mobile spend at least 30 minutes per day in the prone position (*i.e.*, ‘‘tummy time’’).

Alhough it provided PA recommendations for infants and toddlers, the WHO rated the quality of evidence linking PA to health outcomes in that age group as ‘‘very low using the GRADE framework.’’[5] Clearly, there is consensus among key experts that physicians, parents, and care providers need to better understand the health impact of PA in very young children, including infants.

Development and wide application of device-based measurement of PA have enhanced the feasibility of studying the relationships between PA and health in infants. Nonetheless, relatively few studies using device-based measures have examined PA and its health effects in children younger than 3 years, and the number of studies is particularly small for infants younger than 1 year.[6–10] In a recent systematic review, Bruijns et al.[6] identified five published studies on PA in infants. Infants' mean PA level was averaged across these studies and was reported to range from 78.2 to 2580.5 counts/min. However, the samples included in those studies and the methods used to measure PA were quite variable.

Furthermore, only two of those studies were conducted with children in the United States, and both of those studies included relatively small samples and different devices and data reduction procedures.[11,12] Accordingly, major gaps exist in the current body of knowledge and there is a need for well-designed studies with large samples in the field to better understand PA in the infant population.

There are also important gaps in the research on factors that influence PA in young persons, but the nature of these gaps varies widely across age groups. In school-aged children, an extensive body of research has led to the conclusion that PA is affected by a multilevel constellation of personal, social, physical environmental, and policy factors.[13] In children of preschool age, the relevant literature is not as expansive as for school-age children, but studies have shown that social and environmental factors operating in the home and child care settings influence children's PA levels.[14]

Among toddlers, ages 1–2 years, a small number of studies have examined factors that may influence PA, and most are limited by cross-sectional study designs.[15] In infants, the body of knowledge is even more limited in that the small number of pertinent studies have rarely used device-based measures of PA and have typically considered only demographic factors as potential correlates of PA.[16] Hence, there is a need to conduct research that considers a wider range of potential influences on device-based measures of PA in infants.

This study was designed to address some of the limitations in the existing research base on PA in infants by applying a comprehensive device-based protocol to measure PA in a large and diverse sample of infants. The specific aims of the study were (1) to describe objectively measured PA using accelerometers worn at waist and ankle sites in 6–7-month-old infants; (2) to compare objectively measured PA levels across infants grouped by demographic and developmental factors; and (3) to identify the demographic and developmental factors that are independently associated with objectively measured PA in infants.

Materials and Methods

Data in this study were drawn from the Linking Activity, Nutrition, and Child Health study, which aimed to examine PA behavior and associations between PA and other health characteristics in infants. Study participants included infants 6–7 months of age and their mothers in two counties in a Southeastern state in the United States. The sample included both infants who attended and did not attend formal child care centers. Mother-infant dyads were recruited through child care centers, pediatric offices, faith-based organizations, and community events. Additional details regarding the Linking Activity, Nutrition, and Child Health study protocol are reported elsewhere.[17] Before the study, written informed consent was obtained from the mother of each infant. The University of South Carolina's Institutional Review Board approved all protocols. Data were collected on 143 infants, with PA data measured by accelerometry available for 126 at the ankle site and 109 at the waist site.

Measures

Infant PA was measured objectively using accelerometers [ActiGraph GT3X+ model (waist site) and GT9X model (ankle site)]. Before data collection, the accelerometers were initialized to collect data at 80 Hz beginning at midnight on the day of distribution. Infants were fitted with two accelerometers, one at the right waist on an elastic belt and one at the right ankle in a sweatband. These sites were selected to detect limb movement as well as translational movement of the whole body. Parents were instructed to have their infant wear the monitors for a total of 7 days (except during water-based activities).

Trained data collectors provided parents with detailed instructions to support compliance with the accelerometry procedures. Accelerometers were placed at multiple sites because infants in the study were not ambulatory; therefore, we wanted to detect limb movement, affecting the ankle site, as well as movement of the center of gravity, affecting the waist site. In addition, very few studies have reported accelerometry data on multiple placement sites in infants as young as 6 months.[11,18]

Data were collected and stored in 15-second epochs, and any period of ≥60 minutes of consecutive zero counts was defined as non-wear time and was excluded from the analyses. A valid 12-hour day was classified as 8 hours of wear during a 12-hour period from 7 am to 7 pm for wear time. Age-specific cut points for PA intensities have not yet been established for nonambulatory infants; therefore, no intensity cut point was utilized in the analyses. Instead, PA was defined as vector magnitude average counts per hour for both the ankle and waist accelerometer sites.

Infant anthropometric measures of weight and length were assessed by trained data collectors using standard protocols. Weight and height were measured using a Seca Digital Baby Scale (model 334; Chino, CA) and Seca Pediatric Length Board (model 417; Chino, CA). Using WHO growth charts,[19] age- and sex-specific weight-for-length percentiles and z-scores, and age- and sex-specific BMI z-scores, were calculated from weight and length measurements.

The Peabody Developmental Motor Scales-2[20] was used to assess infant motor development. The Peabody Developmental Motor Scales-2 is commonly used in clinical and research settings, with reported sound psychometric properties, including high validity and reliability.[20,21] Trained data collectors administered gross movement subtests according to standard age-specific protocols. Subtests included reflex, stationary, and locomotion performances. The reflex subtest measured the infant's ability to react to environmental occurrences.[20] The stationary subtest measured the infant's ability to control his/her body within its center of gravity and retain equilibrium, and the locomotion subtest measured his or her ability to move from one place to another.[20] For the analyses in this study, the raw scores for the stationary and locomotion subtests were analyzed. Mothers also reported additional information regarding their infant's motor milestones, including the age in months when the infant first rolled over.

Mothers completed a survey to provide additional information regarding demographic, home environment, and care setting characteristics. This included demographic characteristics (*i.e.*, race/ethnicity and education), the social environment (*i.e.*, the number, ages and sex of children living in the home), and the physical environment [*i.e.*, number of resources used by infant in home (*e.g.*, toys and play space), and the number of minutes per day the infant spent in restrictive equipment]. The physical environment data were used to create a restrictive devices index, which included time spent in a bouncer, car seat, or stroller, for use in the analyses.

In addition, mothers provided information regarding their infant's PA behaviors at home, including tummy time (times per day and days per week), time spent playing outdoors on weekdays and weekends, and time spent in a playpen. Mothers were also asked to indicate their infant's current child care situation and the type of child care utilized. For this study, responses were categorized into three types of care settings: (1) child care in the home, (2) child care with a relative, and (3) structured care setting (*e.g.*, commercial and faith based).

Statistical Analysis

Descriptive statistics (means and standard deviations or percentages) were calculated to describe infants' PA, demographic characteristics, physical and care/social environment characteristics, and home PA and environmental factors. Analysis of variances (ANOVAs) was used to compare PA of demographic subgroups, using data from both the waist and ankle accelerometer sites. Pearson correlation coefficients were used to describe bivariate associations between PA measured at the waist and ankle accelerometer sites, and continuous factors hypothesized to be associated with PA. Multiple linear regression analyses were then used to identify factors associated with PA measured by accelerometry.

Relationships with all continuous variables and PA were evaluated and only those with significant relationship from the correlational analysis were added to the regression models. Separate models were conducted for the ankle and the waist accelerometer sites by running a sequential series of models, adding the variables that were found to have a significant relationship with PA through reviewing the correlational analyses results performed previously. Model 1 included motor development variables and the age that the infant first rolled over. Model 2 added care setting, resources used by the infant in the home, and tummy time. Model 3 added the restrictive devices index variable. Finally, Model 4 added sex, race, parent education, if the infant had an older sibling(s), infant's age, and BMI z-score.

Results

Characteristics of the infants are presented in Table 1. On average, infants were 30 weeks of age at the time of

Table 1. Characteristics of the Infants in Whom Physical Activity Was Measured by Accelerometry (*N* = 143)

	N	Percent or mean (SD)
Demographic characteristics		
Age (weeks)	143	29.5 (4.3)
Sex		
Males	75	52.5
Females	68	47.5
Race		
Non-Hispanic White	63	44.1
Non-Hispanic Black	48	33.6
Hispanic	26	18.2
Other	6	4.1
Parent education		
College or above	79	58.1
Less than college	57	41.9
Physical characteristics		
Weight status		
BMI z-score (wt/ht^2)	143	0.43 (1.17)
Weight for length z-score (wt/ht)	143	0.55 (1.14)
Motor development		
Stationary raw score	139	27.5 (5.8)
Locomotion raw score	135	25.8 (9.6)
Care & social environment characteristics		
Care setting		
Home	67	48.6
Relative's home	17	12.3
Structured care	54	39.1
Older siblings		
Yes	96	71.1
No	39	28.9
Home PA & environment factors		
Resources used by infant in home (*e.g.*, toys, play-space)	137	2.6 (1.6)
Weekday outdoor playtime (min/day)	128	41.9 (72.8)
Weekend outdoor playtime (min/day)	131	73.3 (87.5)
Tummy time (times/week)	126	33.4 (29.0)
Age infant first rolled over (months)	132	4.1 (1.2)
Playpen time (min/day)	138	47.4 (101.0)
Bouncer time (min/day)	133	74.8 (83.5)
Car seat time (min/day)	132	56.8 (60.7)
Stroller time (min/day)	127	30.0 (42.8)
Restrictive devices index (*i.e.*, time in bouncer, car seat, stroller) (min/day)	137	155.1 (124.7)

PA, physical activity.

measurement, and 53% were male. The racial and ethnic breakdown of the sample were ∼44% Non-Hispanic White, 34% Non-Hispanic Black, 18% Hispanic, and 4% other. Over 48% of the sample indicated home as their primary care setting, and over 70% had an older sibling. Home PA and environmental factors are also reported in Table 1. Parents reported an average of approximately three resources used by the infant in the home (*e.g.*, toys and play space), and the average age of rolling over was 4 months. Infants spent >70 minutes outdoors on weekend days, and over 2 hours in restrictive devices per day.

Results of one-way ANOVA to compare PA measured by accelerometry across demographic subgroups are presented in Table 2. Significant differences in physical activity were observed between racial groups at both the ankle ($p < 0.001$) and the waist site ($p < 0.01$), with the highest counts per hour recorded in white infants (ankle = 89,131 counts/hr and waist = 36,719 counts/hr). Significant differences in PA were also observed by parent education.

Infants whose parents had more education (college degree or above) had significantly higher counts per hour of PA (ankle = 83,195 counts/hr and waist = 34,783 counts/hr) compared to those whose parents had less education, at both the ankle ($p = 0.001$) and the waist site ($p = 0.01$). In addition, significant differences ($p < 0.05$) in PA were observed between the type of care setting that infants attended, with those in a structured care setting demonstrating the highest PA counts at the ankle site. Results also indicated that infants without older siblings had significantly higher PA counts at the waist site compared to those with older siblings ($p = 0.04$).

Table 3 presents correlations between PA and continuous variables hypothesized to be associated with PA. For the ankle site data, variables positively associated with PA included motor development [locomotion score ($r = 0.33$, $p < 0.001$) and stationary score ($r = 0.19$, $p < 0.05$)], resources used by the infant in the home ($r = 0.24$, $p < 0.05$), and tummy time ($r = 0.31$, $p < 0.01$), and variables negatively associated with PA included age when the infant first rolled over ($r = -0.24$ ($p < 0.05$) and time spent in a stroller ($r = -0.25$, $p < 0.05$).

For the waist site data, variables positively associated with PA included age of the infant at measurement (weeks)

Table 2. Physical Activity Measured by Accelerometry (Counts/Hr) and Comparisons across Demographic Subgroups

	PA (counts/hr)					
	Ankle site			Waist site		
	N	Mean (SD)	*p**	*N*	Mean (SD)	*p**
Total group	126	77,712.9 (25,852.8)		109	32,534.9 (13,130.3)	
Sex			0.21			0.59
Males	65	80,522.2 (26,520.3)		55	33,217.6 (13,014.9)	
Females	61	74,719.3 (24,991.2)		54	31,839.5 (13,332.5)	
Race			<0.001[a–c]			<0.01[b,c]
Non-Hispanic Black	42	63,331.5 (22,517.3)		37	28,312.9 (11,885.8)	
Hispanic	22	79,754.7 (19,182.0)		16	31,935.0 (12,080.7)	
Other	5	59,356.6 (18,847.5)		5	23,018.3 (14,795.3)	
Non-Hispanic White	57	89,131.8 (25,253.9)		51	36,719.1 (13,006.4)	
Parent education			0.001			0.01
Less than college	46	67,014.4 (22,800.9)		40	28,360.5 (12,071.0)	
College or above	74	83,195.6 (25,095.3)		64	34,783.7 (13,269.5)	
Care setting			<0.01[d]			0.05
Home	58	71,895.9 (22,837.9)		49	29,228.8 (13,349.9)	
Relative's home	16	66,500.1 (13,039.4)		13	33,300.7 (19,183.5)	
Structured care	48	87,576.1 (28,709.3)		44	36,012.4 (13,232.1)	
Older siblings			0.18			0.04
No	35	82,212.0 (24,152.7)		29	36,521.9 (13,144.1)	
Yes	84	75,355.2 (26,004.7)		75	30,630.3 (12,736.0)	

**p*-Values are from an ANOVA.
[a]Non-Hispanic Black and Hispanic differ.
[b]Non-Hispanic Black and Non-Hispanic White differ.
[c]Other and Non-Hispanic White differ.
[d]Home and Relative do not differ.
ANOVA, analysis of variance.

($r = 0.43$, $p < 0.001$), motor development [locomotion score ($r = 0.57$, $p < 0.001$) and stationary score ($r = 0.53$, $p < 0.001$)], resources used by the infant in the home ($r = 0.33$, $p < 0.01$), and tummy time ($r = 0.27$, $p < 0.01$). Variables negatively associated with PA included the age when infant first rolled over ($r = -0.29$ ($p < 0.01$) and for the restrictive devices index (min/day) ($r = -0.23$, $p < 0.05$). No further variables were significantly related to PA (*i.e.*, weekend outdoor play time and time spent in a playpen).

Results of the multiple regression analyses are presented in Tables 4 and 5. The sample sizes of the four models differ due to missing values for some of the independent variables. As a sensitivity check, the final model was replicated using full information maximum likelihood estimation so that all observations could be included, despite the sporadic missing data. Results of the two procedures were nearly identical. Therefore, results from the regression models using least squares were reported and interpreted in this study. Results from Model 4, the final model, are reported for both the ankle and waist sites.

Table 4 displays the results of the multiple regression analyses for PA measured at the ankle site (counts per hour). In the final model, infant PA was positively associated with motor development locomotion score ($B = 666.3 \pm 329.8$, $p < 0.05$). Infants whose care setting was at home ($B = -13{,}724.4 \pm 5083.9$, $p < 0.05$) were less physically active than infants in a structured care setting. Infant's tummy time (min) was positively associated with PA ($B = 213.5 \pm 79.9$, $p < 0.05$). In addition, findings

Table 3. Pearson Correlations between Physical Activity Measured by Accelerometry and Factors Hypothesized to be Associated with Physical Activity

	PA	
	Ankle site	Waist site
Infant characteristics		
Age (weeks)	0.14	0.43***
Weight status		
Weight for length z-score (wt/ht)	0.01	0.14†
BMI z-score (wt/ht²)	0.01	0.17‡
Motor development		
Stationary raw score	0.19*	0.53***
Locomotion raw score	0.33***	0.57***
Home PA & environment factors		
Resources used by infant in home (e.g., toys, play space)	0.24*	0.33**
Weekday outdoor playtime (min/day)	0.03	0.07
Weekend outdoor playtime (min/day)	0.12	0.13
Tummy time (times/week)	0.31**	0.27**
Age infant first rolled over (months)	–0.24*	–0.29**
Playpen time (min/day)	–0.11	–0.13
Bouncer time (min/day)	–0.03	–0.13†
Car seat time (min/day)	–0.13†	–0.19‡
Stroller time (min/day)	–0.25*	–0.19‡
Restrictive devices index (i.e., time in bouncer, car seat, stroller) (min/day)	–0.14†	–0.23*

†$p<0.20$, ‡$p<0.10$, *$p<0.05$, **$p<0.01$, ***$p<0.001$.

indicated that non-Hispanic Black infants ($B=-19{,}953.4\pm 5888.5$, $p<0.01$) were less physically active than non-Hispanic White infants.

The results for the multiple regression analyses for PA measured at the waist site (counts per hour) are presented in Table 5. Consistent with findings from the ankle site, infant motor development locomotion scores were found to be consistently positively related to PA ($B=391\pm 179.4$, $p<0.05$) at the waist site. To verify that assumptions underlying the linear regression model were met, diagnostic plots were examined. These plots indicated constant variance and linearity.

Discussion

We found that PA, measured by accelerometry at the ankle and waist sites, was highly variable in a diverse group of 6–7-month-old infants. Accelerometry counts were markedly higher at the ankle site than the waist site, and the standard deviation for accelerometry counts was approximately one-third of the mean at both sites. The key finding of this study was that, when multivariate analyses were applied to PA measured at the ankle site, a diverse set of factors was found to be independently associated with accelerometry counts. These included indicators of motor developmental status, tummy time, child care setting, and race/ethnicity.

These findings indicate that PA behavior in infants is associated with both demographic moderators and factors that are influenced by parents and other caregivers. Both longitudinal and experimental studies are needed to determine if these relationships persist or change as infants develop, and to explore how and why these factors relate to and/or affect infants' development.

An important observation in this study was that in a large and diverse sample of infants, we found multiple demographic subgroup differences in device-based measures of PA. Differences in infants' PA were observed between racial and ethnic groups, with the highest counts per hour of PA among non-Hispanic White infants. In addition, we found that infants whose parents had more education had higher counts of PA compared to infants whose parents had less education. A study conducted by Benjamin-Neelon et al. also identified race and family income as significant covariate predictors when examining PA and adiposity in a racially diverse cohort of US infants.[8] It was particularly notable that we did not identify a sex difference in infants' PA, because it is well known that as boys get older, they are consistently more active than girls.[22]

For example, Trost et al. examined age and sex differences using objectively measured PA in a sample of students in grades 1–12 and found that boys were more active than girls across all grade groups.[22] Our data suggest that a sex difference in PA may emerge in childhood, but not necessarily in infants as young as 6–7-months of age. Overall, very few previous studies have considered demographic factors when studying PA among infants,[8,11,23,24] and those that have did not specifically examine associations between the demographic factors and infant PA. In some cases, this has been studied in school-age children,[13] but there is a clear need for a more careful examination of this topic among infants.

In this study, infants' motor development and time spent in tummy time were consistently and positively related to PA. We are not aware of any previous study that has examined these factors using an objective measure of PA and a direct observation measure of motor development on a large sample of infants. However, some studies of preschool children[16,25] and older children[26,27] have reported associations between motor development and PA, and our findings are consistent. This study also found that the time infants spent in tummy time was consistently and positively related to PA in both the correlation and multivariate analyses.

Table 4. Multiple Regression Analyses for Identification of Factors Associated with Physical Activity Measured by Accelerometry at the Ankle Site

	Model 1 $N = 112$	Model 2 $N = 104$	Model 3 $N = 103$	Model 4 $N = 100$
	B (SE)	*B* (SE)	*B* (SE)	*B* (SE)
Intercept	81,759.6 (15,426.6)***	72,961.2 (16,234.8)***	71,745.5 (17,184.3)***	96,807.3 (20,202.0)***
Motor development				
Locomotion raw score	723.9 (316.5)*	621.7 (313.1)†	628.1 (317.5)†	666.3 (329.8)*
Stationary raw score	−240.7 (493.6)	−307.0 (491.4)	−296.7 (499.9)	−288.5 (493.2)
Age infant first rolled over (months)	−3977.9 (2006.4)†	−1857.3 (2049.0)	−1827.8 (2095.3)	−970.5 (1928.1)
Care setting				
Home		−10,180.7 (4977.8)*	−10,142.5 (5054.1)†	−13,724.4 (5083.9)*
Relative		−17,604.6 (7528.4)*	−17,645.1 (7615.4)*	−11,680.0 (7244.3)
Structured		Ref	Ref	Ref
Resources used by infant in home		1806.2 (1579.2)	1793.3 (1605.4)	817.3 (1536.3)
Tummy time (min)		226.0 (85.5)**	226.6 (86.9)*	213.5 (79.9)*
Restrictive devices index (min/day)			4.6 (19.8)	−6.0 (18.9)
Sex				
Males				4188.3 (4390.4)
Race				
Non-Hispanic Black				−19,953.4 (5888.5)**
Hispanic				4555.0 (6609.1)
Other				−19,814.3 (10,336.9)†
Non-Hispanic White				Ref
Parent education				
Less than college				−1950.8 (5051.4)
Older siblings				
No				5418.3 (5044.5)
Age (weeks)				−725.4 (674.5)
BMI z-score (wt/ht^2)				−1262.1 (1896.8)
R^2	0.11	0.24	0.24	0.41
Adjusted R^2	0.09	0.19	0.17	0.30

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, †$p < 0.10$.

Although experts recommend that infants spend time on their tummy to promote movement and encourage acquisition of important motor skills and head and trunk control,[5,28] little research has examined how tummy time directly relates to infants' PA. These findings suggest that health care professionals should encourage tummy time and other developmentally appropriate activities to increase the acquisition of motor skills and PA among infants.

A notable finding of this study was that we observed differences in PA of infants based on their child care setting. Infants who attended a structured care setting were more physically active than those who received care at home or with a relative. While previous studies in infants have not identified factors that would explain high physical actively levels in the child care setting, future studies should consider that infants who attend structured child care programs may spend more time on the floor and less time being held or in a restraining device, allowing more movement, compared to infants who are cared for at home.

Studies on preschool-age children have reported associations between child care center characteristics and PA.[29,30] For example, in family child care homes, provision of active

Table 5. Multiple Regression Analyses for Identification of Factors Associated with Physical Activity Measured by Accelerometry at the Waist Site

	Model 1 $N=97$	Model 2 $N=90$	Model 3 $N=89$	Model 4 $N=87$
	B (SE)	*B* (SE)	*B* (SE)	*B* (SE)
Intercept	9749.4 (7430.0)	2281.3 (8227.8)	3034.9 (8656.0)	3697.5 (10,975.0)
Motor development				
Locomotion raw score	516.5 (143.9)**	511.8 (149.7)**	510.7 (151.7)**	391.0 (179.4)*
Stationary raw score	571.5 (234.4)*	549.6 (242.6)*	529.0 (246.9)*	406.5 (274.0)
Age infant first rolled over (months)	−1564.0 (959.7)	−635.1 (1003.0)	−761.5 (1027.1)	−1008.4 (1045.5)
Care setting				
Home		−711.2 (2417.6)	−890.0 (2452.1)	449.3 (2681.5)
Relative		−977.1 (3664.6)	−841.1 (3711.0)	1239.6 (3955.8)
Structured		Ref	Ref	Ref
Resources used by infant in home		971.5 (780.8)	1031.0 (792.5)	733.1 (853.9)
Tummy time (min)		73.8 (40.2)†	76.8 (40.8)†	77.0 (41.2)†
Restrictive devices index (min/day)			0.40 (9.3)	−0.12 (9.8)
Sex				
Males				2378.9 (2343.0)
Race				
Non-Hispanic Black				−1651.8 (3292.0)
Hispanic				−1063.8 (3790.0)
Other				−8647.5 (5213.8)
Non-Hispanic White				Ref
Parent education				
Less than college				−361.8 (2764.5)
Older siblings				
No				2949.4 (2728.6)
Age (weeks)				279.3 (376.7)
BMI z-score (wt/ht^2)				86.8 (1037.6)
R^2	0.32	0.40	0.41	0.44
Adjusted R^2	0.31	0.35	0.35	0.35

*$p<0.05$, **$p<0.01$, †$p<0.10$.

play, the availability of play equipment, adequate indoor space, provider behavior during active play, and provider training have been identified as factors that are positively associated with PA among preschool-age children.[29] However, no prior study has examined PA and child care characteristics using objectively measured PA in infants as young as 6 months. Thus, to our knowledge, our study is the first to demonstrate an association between infant PA and child care setting. Future research should continue to examine the child care environment as a setting in which to increase PA in infants.

An important aim of this study was to use a comprehensive device-based protocol to describe objectively measured PA in a large and diverse sample of infants. For infants in this study, we recorded ~77,700 vector magnitude average counts per hour at the ankle site and ~32,500 vector magnitude average counts per hour at the waist site. A recent review conducted by Bruijns et al. identified five studies of infants that measured PA by accelerometry.[6] Due to the lack of existing validated cut points for infants, activity data were summarized in counts per minute to allow for direct comparison across studies.

However, the authors noted that even in this raw form, heterogeneity in infant PA levels remained evident.[6] Across the five studies, reported mean PA level was 1494 counts/min, ranging from 78 to 2580 counts/min.[6] Mean PA level in our study's sample (ankle = 77,712 counts/hr and waist = 32,534 counts/hr) is lower compared to those reported by Bruijns et al. (89,664 counts/hr). Due to variations between studies in methodologies, such as epoch length and wear time, it is difficult to compare the findings of this study to the existing literature.[6] More research is needed to improve clinicians' and researchers' understanding of infant PA behaviors, using psychometrically sound methodological approaches.

This study has important strengths, and some limitations that should be noted. The sample of infants is relatively large and racially and ethnically diverse compared to previous studies of children younger than 12 months,[9–12,23,24,31,32] which allowed us to examine differences in PA among demographic subgroups. An additional strength was the ability to measure and compare two accelerometer sites in our analyses. To our knowledge, only three previous studies have reported PA levels on two accelerometry placement sites in infants.[11,18,33] Furthermore, only two of those studies[11,18] measured infants as young as 6 months, and neither included waist placement.

It is important to note that the way in which the accelerometry data were classified could be considered a limitation of this study. PA data were presented in average vector magnitude counts per hour because we were unable to classify the activity counts into meaningful intensities commonly used in PA research, as cut points have not been established for infants. In addition, we were not able to differentiate movement performed by the infant independently compared to movement when being carried by an adult caregiver. Finally, the cross-sectional nature of this study could also be considered a limitation, as we could not infer causal relationships.

Conclusions

In summary, PA was measured by accelerometry in a diverse sample of 6–7-month-old infants. PA was higher with accelerometers worn at the ankle site than the waist site. Univariate and multivariate analyses identified several infant, social, and physical environmental factors that were associated with PA as assessed with ankle accelerometry. Higher levels of PA were independently associated with more advanced motor developmental status, attendance at a structured child care setting, and greater exposure to tummy time. Future research should use longitudinal study designs in examining the effects of a comprehensive set of social and physical environmental factors and individual-level characteristics on the development of objectively measured PA during infancy and early childhood. Furthermore, future studies should aim to inform PA guidance for very young children by examining associations between PA and health parameters such as weight and adiposity.

Authors' Contributions

E.R.S. and R.R.P. conceptualized and designed the study; R.R.P. and K.L.M. supervised and administered the study; M.D. analyzed and interpreted the data; E.R.S. and R.R.P. drafted the article and revised the article; and all authors edited the article and approved the final version of the article.

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Author Disclosure Statement

No competing financial interests exist.

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