Pediatric Exercise Science, 2018, 30, 266-272
https://doi.org/10.1123/pes.2017-0074

Human Kinetics
ORIGINAL RESEARCH

How Does the Relationship Between Motor Skill Performance and Body Mass Index Impact Physical Activity in Preschool Children?

Haixia Guo
Xi'an University of Architecture and Technology

Michaela A. Schenkelberg, Jennifer R. O'Neill, Marsha Dowda, and Russell R. Pate
University of South Carolina

Purpose: To determine if weight status modifies the relationship between motor skill (MS) performance and physical activity (PA) in preschoolers. ***Methods:*** Preschoolers ($N = 227$, age 3–5 y) were recruited from 22 preschools. Preschoolers' MS (locomotor, object control, and total MS) were assessed with the Children's Activity and Movement in Preschool Study MS protocol. PA was measured by accelerometry. Mixed linear models were used to examine the relationship of MS performance and body mass index (BMI) *z* score to PA. Models were adjusted for age, race, sex, and parent education, with preschool as a random effect. ***Results:*** There was a significant correlation between MS performance and PA ($r = .14–.17$, $P < .05$). A significant interaction was observed between BMI *z* score and object control, and between BMI *z* score and total MS score on PA ($P = .03$). Preschoolers with higher BMI *z* scores and high object control scores engaged in significantly ($P = .03$) more PA than preschoolers with lower BMI *z* scores and high object control scores (PA = 15.04 min/h and 13.54 min/h, respectively). Similarly, preschoolers with higher BMI *z* scores and high total MS scores spent significantly ($P = .01$) more time in PA compared with those with lower BMI *z* scores and high total MS scores (PA = 15.65 min/h and 13.91 min/h, respectively). ***Conclusion:*** Preschool children's MS performance is positively correlated with PA, and BMI *z* score modified the relationship between MS performance and PA.

Keywords: locomotor skill, object control skill, motor competency, weight status, overweight and obesity

The prevalence of childhood overweight and obesity has increased precipitously in recent years in the United States (27,28,37) and around the world (7), and physical activity (PA) has been identified as one of the key factors for addressing childhood obesity (17,18,32). Even for young children, participation in a greater amount and variety of PAs is conducive to long-term healthy weight maintenance (19). Many children of preschool age (3–5 y) are insufficiently active (14,30,31) and do not meet new PA guidelines (14,29). Understanding the correlates of PA in young children can guide development of multilevel interventions that may offer the best chance for increasing PA.

Previous studies have described the multiple physiological, psychosocial, and behavioral factors that are associated with PA in children (4,15,25,35). Of these factors, children's motor skills (MSs) are consistently and positively correlated with PA (2,15,25). MSs are a set of purposeful, goal-directed movements that are essentially the building blocks of a child's movement repertoire, which establish the foundation for later movement (5). Features of the environment influence MS development, as do certain biological processes such as growth (23). Measurements of height and weight are commonly used to determine children's body mass index (BMI) and to monitor growth. BMI and other measures of adiposity have been found to be consistently correlated with MSs among children and adolescents (2); however, there is inconclusive evidence of the association between BMI and PA behaviors of children (35).

Few studies, however, have explored the influence of BMI on the relationship between motor performance and PA behaviors of children (2). Existing studies that focused on older children and adolescents found that weight status did not significantly influence the relationship between MS performance and PA (16,26). It remains to be determined if this finding holds true for younger children under the age of 6 years. Williams et al

Guo is with the Dept. of Physical Education, Xi'an University of Architecture and Technology, Xi'an, China. Schenkelberg, O'Neill, Dowda, and Pate are with the Dept. of Exercise Science, University of South Carolina, Columbia, SC. Address author correspondence to Michaela A. Schenkelberg at schenkm@email.sc.edu.

(40) assessed the MSs and accelerometer-derived PA levels of 198 preschool children aged 3–4 years. Children with more developed MSs were found to be significantly more active than those with poorer motor scores. However, that study did not investigate the association between MS performance and BMI with preschoolers' PA. Therefore, the aim of this study was to build upon the findings of Williams et al (40) and determine if weight status modifies the relationship between MS performance and PA of preschool children.

Methods

Participants

Data for the current study were collected as part of the Children's Activity and Movement in Preschool Study (CHAMPS). The methods of the study have been reported in detail elsewhere (39,40) and are briefly described here. Participants included in the present study were 227 children aged 3–5 years enrolled in CHAMPS. Participants attended one of the 3 types of preschools: commercial ($n = 11$), religious-based ($n = 7$), and Head Start ($n = 4$), and all 3- to 5-year-old children in each preschool were invited to participate. Data collection for each participating child occurred once during one of the 2 data collection sessions. These sessions took place over the course of 18 months (from Aug 2004 to Jan 2006) to account for the effect of seasonality. If preschools had more than 18 consented children in each data collection session, participants were randomly selected. Written informed consent was obtained from each child's guardian prior to data collection. The University of South Carolina's institutional review board provided ethical approval for the study.

Measures

MS Performance. Gross MS performance was assessed using the CHAMPS MS protocol (CMSP), a standardized MS protocol that assesses the movement process characteristics of 6 locomotor and 6 object control skills. The CMSP has been validated for 3- to 5-year-old children (39) and has high concurrent validity ($r = .94–.98$) with the Test of Gross Motor Development —second edition (39). Additionally, the CMSP has been found to have high ($r > .90$) test and interobserver reliability. Two demonstrations per skill were given to the child, who then performed 2 trials for each skill. The sequence of locomotor skills was run, jump, slide, gallop, leap, and hop. The sequence for object control skills was throw, roll, kick, catch, dribble, and strike. Movement process characteristics were determined as present ("1") or absent ("0") by 2 trained testers. There were 3 exceptions for this rating system. For "hop," no hop was rated "0," a stationary hop was rated "1," and a moving hop was rated "2." For "throw" and "strike," hip-and-trunk rotation was scored as "0" (no rotation), "1" (block), and "2" (differentiated) (39). Each participant received 3 scores: locomotor, object control, and total motor score, a composite score that was calculated by summing locomotor and object control scores from both trials. High scores indicated a better mastery of MS performance. The range of possible scores was 0–73 for locomotor skills, 0–80 for object control skills, and 0–153 for total motor score.

Physical Activity. PA (light, moderate, and vigorous) was measured using accelerometers (7164; ActiGraph, Fort Walton Beach, FL) that captured data in 15-second epochs, due to the spontaneous nature of young children's PA behaviors (1). Children wore the accelerometers, which were attached to an elastic belt, over their right hip during all waking hours and naps at school for 8–10 days and at home for a weekend. A valid day was defined as 5–17 hours of total daily wear time, and only children with ≥3 days of valid accelerometer data were included in the analyses. Days during which a child was absent from preschool were not included in the analyses. Sixty minutes of consecutive zeros were considered nonwear time and were not considered in the calculation of total wear time. Age-specific count cut points (≥200 counts per 15 s) were applied to determine participants' minutes of total PA (9). To control for wear time, minutes of total PA for each participant was divided by their total wear time, yielding average time spent (minutes per hour) in total PA.

Body Mass Index. Height was measured to the nearest 0.1 cm using a portable stadiometer (Shorr Productions, Olney, MD). Weight was measured to the nearest 0.1 kg using an electronic scale (model 770; Seca, Hamburg, Germany). The average of 2 measurements was used for both height and weight. BMI was calculated and expressed as kg/m^2. BMI z score, an appropriate estimate of children's adiposity on a single occasion (20), was created by assessing the deviation of each participant's value from the age- and sex-specific mean values reported in the Centers for Disease Control and Prevention growth charts (20).

Analyses

Descriptive statistics for demographic, PA, BMI z score, and MS performance variables were calculated. Pearson correlations were calculated for the total group to determine correlations between BMI z score and MS performance (locomotor, object control, and total motor scores) and PA. Mixed linear regression models were created to investigate the independent associations of BMI z score and MS scores, as well as interactions between these 2 variables with PA, the dependent variable. Use of BMI z score as a continuous variable affords more power to detect main and interaction effects. Interaction terms were retained in the final model if found to be significant. Significant interactions were then examined further by stratifying participants into low and high BMI z score groups (median split) and low, intermediate, and high groups for MS performance.

This allowed for a more interpretable examination of the effect of BMI *z* score on PA, the dependent variable, within MS performance groups. All models were analyzed with PROC MIXED (SAS version 9.3; SAS Institute Inc., Cary, NC) and adjusted for age, race/ethnicity, sex, and parent education, with preschool as a random effect. Statistical significance was set at a level of .05.

Results

Descriptive data for the total sample of participants are presented in Table 1. There were significant, positive correlations between the 3 MS performance variables (locomotor, object control, and total motor score) and PA. Locomotor score ($r = .14$, $P < .05$), object control score ($r = .16$, $P < .05$), and total MS score ($r = .17$, $P < .001$) each significantly correlated with PA. There was no significant correlation between BMI *z* score and MS performance ($r = .01–.11$, $P > .05$). Additionally, there was no significant correlation between BMI *z* score and PA ($r = .11$, $P > .05$).

Results of the mixed linear regression models are presented in Table 2. Locomotor score was significantly ($P = .03$) and independently positively associated with minutes of PA in the adjusted model. There was no interaction effect between BMI *z* score and locomotor score on PA. There were no significant independent associations between BMI *z* score, object control score, or total motor score on PA (see Table 2); however, there were significant interaction effects. BMI *z* score significantly modified the relationship between object control score and PA ($P = .03$) in the adjusted models. Likewise, BMI *z* score significantly modified the relationship between total motor score and PA ($P = .03$).

The 2 significant interaction effects were further explored by stratifying object control and total motor scores in low, intermediate, and high groups, and BMI *z* score in low and high groups. Children who scored high in object control and who had high BMI *z* scores obtained 1.50 more minutes per hour of PA ($P = .03$) compared with children with low BMI *z* scores and high object control scores (see Figure 1). Similarly, children in the high total motor score group with high BMI *z* scores obtained 1.74 more minutes per hour of PA ($P = .01$) compared with children in the high total motor score group with low BMI *z* scores (see Figure 1). There were no other significant differences found between BMI *z* score groups within the low or intermediate levels of MS performance groups.

Table 1 Demographic Characteristics of Participants

	Participants
N	227
Age, mean (*SD*), mo	49.8 (7.5)
3-year-olds, %	44.1
4-year-olds, %	47.5
5-year-olds, %	8.4
Sex, male, %	48.9
Healthy weight, %	75.7
Overweight/obese, %	24.3
Race/ethnicity, %	
white	40.1
African American	51.1
other	8.8
Parent education, %	
high	54.6
low	45.4
BMI, mean (*SD*), kg/m^2	16.3 (2.3)
BMI-*z*, mean (*SD*)	0.3 (2.1)
Total PA, mean (*SD*), min/h	14.3 (3.1)
Locomotor score, mean (*SD*)	39.2 (11.8)
Object control score, mean (*SD*)	45.3 (11.6)
Total motor score, mean (*SD*)	84.5 (20.9)

Abbreviations: BMI, body mass index; PA, physical activity.

Discussion

The present study objectively measured the MSs and PA levels of preschoolers and found that there was a significant, positive relationship between preschoolers' MSs and time spent in PA. This is consistent with other studies that have found that preschool-aged children with greater proficiency in MSs were more physically active than less proficient movers (6,12,40). Figueroa and An (10) recently reviewed 11 studies to explore the relationship between MSs and preschoolers' PA. Eight of the studies reported a significant positive relationship between MSs and PA; however, it is yet to be determined whether MS proficiency results in or is the result of, PA participation.

Demographic factors, such as weight status, often influence young children's MS proficiency and PA (2,22,41). D'Hondt et al (8) assessed the gross MSs and weight status of children (6–10 y) in a longitudinal study and found that overweight and obese children ($n = 50$) had poorer MSs than healthy weight peers ($n = 50$), and the differences in MSs between the 2 groups widened over time. Similarly, a greater BMI among school-aged children (8–10 y) was associated with poorer MS proficiency and lower levels of PA (41); however, this relationship has been less frequently investigated among preschool-aged populations. Similar to the present study, Logan et al (22) found that there was a nonsignificant correlation between preschoolers' ($n = 38$) BMI *z* score and MSs; however, when BMI percentiles were grouped into high, medium, and low categories, heavier preschoolers demonstrated significantly lower motor proficiency. The present study also found that there was no independent association between BMI *z* score and preschoolers' PA, which is consistent with other studies of

Table 2 Results of Regression Analyses for Prediction of Time in PA Among Preschoolers (*N* = 227)

	Unadjusted			Adjusted[a]		
	β	*SE*	*P*	β	*SE*	*P*
Model 1: BMI *z* score, locomotor score						
BMI *z* score	0.17	0.10	.08	0.18	0.09	.06
locomotor score	0.04	0.02	.04	0.04	0.02	.03
BMI *z* score × locomotor score	–	–	–	–	–	–
Model 2: BMI *z* score, object control score						
BMI *z* score	−0.32	0.27	.23	−0.39	0.40	.09
object control score	0.03	0.02	.07	0.02	0.01	.17
BMI *z* score × object control score[b]	0.02	0.01	.06	0.02	0.01	.03
Model 3: BMI *z* score, total motor score						
BMI *z* score	−0.54	0.40	.18	−0.70	0.40	.09
total motor score	0.02	0.01	.06	0.02	0.01	.17
BMI *z* score × total motor score[b]	0.01	0.01	.08	0.01	0.01	.03

Abbreviations: BMI, body mass index; PA, physical activity.
[a]Adjusted for race/ethnicity, parent education, sex, and age.
[b]Interaction terms were only retained in the final model if found significant.

preschool-aged children (6,11,13). These findings suggest that there is a complex relationship between indicators of obesity, such as BMI *z* score, and motor proficiency and PA, and highlight the importance of exploring how these variables interact (22).

Although there were no significant, independent associations between BMI *z* score and MSs or PA, the present study found that BMI *z* score modified the relationship between 2 MS variables (object control and total motor score) and PA. Specifically, heavier children

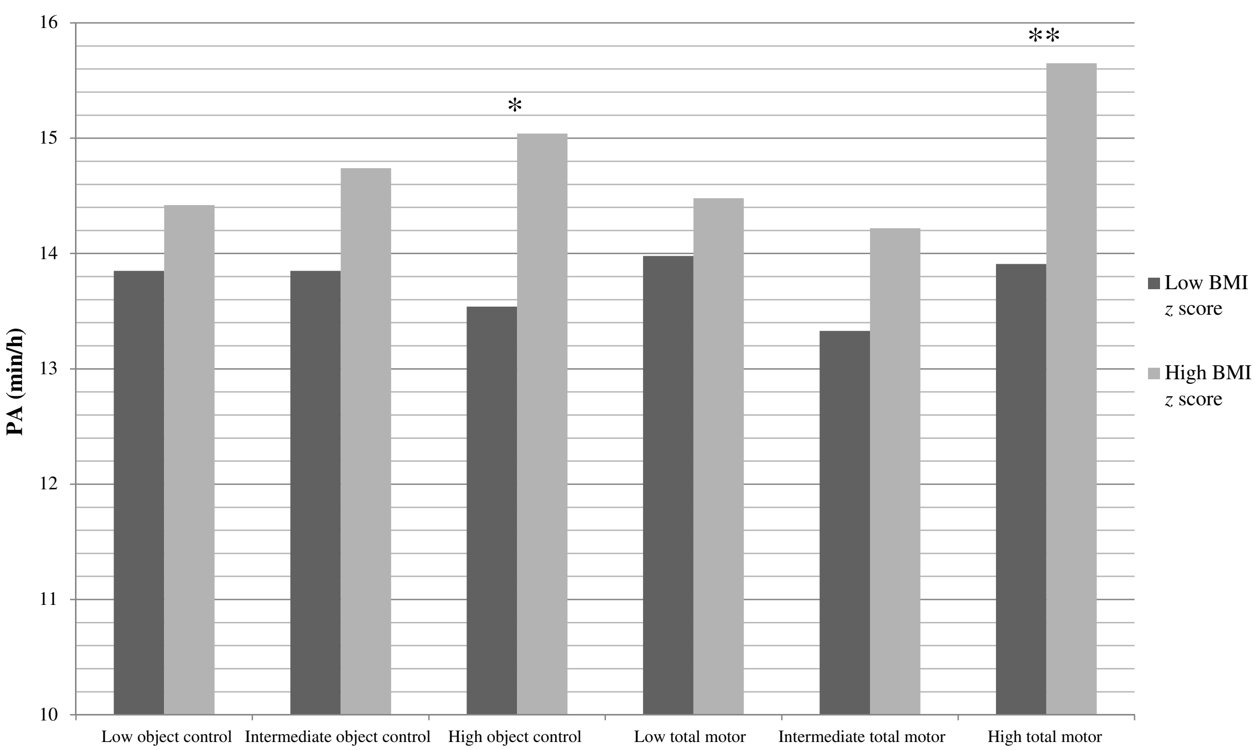

Figure 1 — Interactions between BMI *z* scores, MSs (object control and total motor score), and PA. BMI indicates body mass index; MS, motor skill; PA, physical activity. *$P = .03$. **$P = .01$.

with higher MS scores were significantly more physically active than lighter children with higher MS scores. This finding conflicts with the hypothesis that heavier children are less physically active as a result of poorer motor proficiency (22). It may be that heavier children are more skilled than the lighter children due to differences in their rate of development (3). The interaction effects found in the present study were similar to those of a study of Danish school-aged children (age 6–8 y; $N = 327$), which found that boys with greater body fat and higher MSs were more physically active than boys in the low fat and lower MS group (26). Additionally, girls with greater body fat and higher MS scores were more physically active than girls in other groups (26). The effect of weight on the relationship between motor proficiency and PA was not observed among older children (age 9–12 y) (16).

Notably, the interaction effect in the present study was only significant for object control and total motor score and not for locomotor score. Heavier children may have more force, or strength, for execution of object control skills, but may not be as advanced with locomotor skills given that they require moving mass through space (36). Therefore, these children may be more frequently engaging in object control–specific activities and avoiding locomotor activities, thus limiting opportunities for locomotor skill development. Further, it may be that preschoolers' object control skills accounted for a large portion of the composite total MS score, thus driving the significant interaction. However, when we explored the interactions by overweight (≥85th percentile) and nonoverweight (<85th percentile), there were no differences between groups (data not shown).

The results of the present study are not intuitive and may also be a function of growth and rapidly changing body composition, which is not accurately captured by BMI *z* score. BMI *z* score is an appropriate estimation of a child's relative weight status (20), but it does not account for differences in fat mass and fat-free mass. Fat-free mass, which includes muscle mass and bone density, increases at a faster rate than fat mass during early childhood as children approach adiposity rebound (24), thus decreasing percent body fat. Therefore, greater BMI *z* score values in the present study may be the result of improved body composition and indicative of the preschoolers' healthy development. Alternatively, children with greater BMI *z* scores may be experiencing early adiposity rebound, which has been associated with advanced skeletal maturity (33,34), resulting in more proficient movers. However, we are unable to determine participants' age of adiposity rebound in the present study because more data points are necessary (34).

Methodological protocols for assessing children's MSs vary across studies and can be categorized into process- or product-oriented assessments (10). The latter focuses on performance outcomes (eg, the number of times a child dribbled a ball) and provides important quantitative information about the status of the child's MSs (38). Process-oriented assessments, however, allow for comprehensive accounts of the form and quality of children's movements and tend to be the primary approach for assessing preschoolers' MSs (38). The CMSP was selected as the MS assessment protocol for the present study because, while it does not provide a quantitative account of children's MSs, it comprehensively assesses the quality of 12 locomotor and object control skills that are relevant to the preschool population. The protocol has been previously validated for this age group and was designed for use in large studies (39). Further, compared with other process-oriented assessments, the CMSP allows for a more comprehensive understanding of the locomotor and object control skills of preschoolers through more detailed scoring of skill performances, resulting in a wider range and wider distribution of scores. Although we consider these factors to be a strength of the present study, it should be noted that MS assessment protocols that incorporate both product and process components are becoming increasingly recommended by experts in the field (10,21).

The present study consisted of a racially and socioeconomically diverse sample of children who were enrolled in a variety of preschool settings (commercial, religious-based, and Head Start). This is a major strength of the study as is the utilization of accelerometers to objectively measure PA. However, the cross-sectional design is a limitation of the present study, which prevents making causal inferences and warrants consideration. Additionally, some studies have found that the relationship between MSs and PA varies by sex (2,7,15). Although the analyses in the present study controlled for sex, the influence of sex on the interaction of BMI *z* score, MSs, and PA is unclear. It may be beneficial to stratify by sex in future studies.

Conclusion

To our knowledge, the present study is the first to explore the interaction between BMI *z* score and MSs on PA behaviors of preschool-aged children. Although BMI *z* score was not a significant, independent predictor of PA, it was a significant modifier in the relationship between object control skills and PA and total MSs and PA. Given the limitations of BMI *z* score as a measure of adiposity, it may be beneficial to explore these relationships using other measures of body composition. The finding that, among children with high MSs, heavier children were more active than lighter children suggests the need for a better understanding of the complex relationship between MSs, weight status, and PA of preschool-aged children. Longitudinal studies are warranted to further explore these relationships and to determine causal pathways that could direct the development of evidence-based early childhood MS interventions.

Acknowledgments

The authors would like to thank Erica Y. Lau (PhD) and Xuemei Sui (MD, MPH, and PhD) for their assistance with manuscript preparation, and Gaye Groover Christmus (MPH) for editing this manuscript. We also appreciate all the participants in the study. This study was supported by 2 grants from the National Institutes of Health (R01HD043125-04 and R01HD043125-02S1). The authors have no conflicts of interest to disclose.

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