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Fundamental motor skill, physical activity, and sedentary behavior in socioeconomically disadvantaged kindergarteners

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ABSTRACT

Guided by Stodden et al's conceptual model, the main purpose of the study was to examine the relation between fundamental motor skills (FMS; locomotor and objective control skills), different intensity levels of physical activity (light PA [LPA], moderate-to-vigorous PA [MVPA], and vigorous PA[VPA]), and sedentary behavior (SB) in socioeconomically disadvantaged kindergarteners. A prospective design was used in this study and the data were collected across the 2013–2014 academic school year. Participants were 256 (129 boys; 127 girls; $M_{age} = 5.37$, SD = 0.48) kindergarteners recruited from three public schools in the southern United States. Results found that FMS were significantly related to LPA, MVPA, VPA, and SB. Regression analyses indicate that locomotor skills explained significant variance for LPA (6.4%; $p < .01$), MVPA (7.9%; $p < .001$), and VPA (5.3%; $p < .01$) after controlling for weight status. Mediational analysis supports the significant indirect effect of MVPA on the relation between FMS and SB (95% CI: [−0.019, −0.006]). Adequate FMS development during early childhood may result in participating in more varied physical activities, thus leading to lower risk of obesity-related behaviors.

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Introduction

The major topic of discussion in the area of childhood obesity focuses on the health indicators and the behavioral determinants of obesity such as physical activity (PA) and sedentary behavior (SB) in the pediatric population (Salmon, Tremblay, Marshall, & Hume, 2011; Tremblay et al., 2011). Health professions recommend that school-aged children should accumulate at least 60 min of moderate-to-vigorous physical activity daily (MVPA; Troiano, Berrigan, Dodd, Masse, & McDowell, 2008; U.S. Department of Health & Human Service [USDHHS], 2008). Researchers also indicated that children spend majority of the day being sedentary (6–8 h; e.g. sitting time, TV viewing, and video gaming; Tremblay et al., 2011), and spend less than 5% of the day in MVPA (Basterfield et al., 2011; Pate et al., 2004). In addition, children who come from lower-income families have been identified as one of the most high-risk groups for overweight and other potential risk behaviors such as lower levels

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of sport participation, spending more time on television/video viewing, and more hours of daily non-school computer use (Centers for Disease Control & Prevention [CDC], 2012).

Numerous studies already documented a negative relation between PA and excessive body mass index (BMI) among children, whereas recent research efforts on the importance of SB remain inconsistent (Prentice-Dunn & Prentice-Dunn, 2012; Tremblay et al., 2011). According to those reviews, SB is proposed as an independent risk factor for obesity, regardless of an individual's PA level. And, the dose-response association of PA and SB remains unclear and lacks of investigation especially among young children (Prentice-Dunn & Prentice-Dunn, 2012). A growing body of evidence indicates that fundamental motor skill (FMS) contribute to children's physical and psychosocial development and provide the foundation for an active lifestyle (Logan, Robinson, Wilson, & Lucas, 2012; SHAPE America, 2014). FMS are commonly developed in early childhood including locomotor (e.g. hopping and sliding) and object control skills (e.g. dribbling and throwing; Logan et al., 2012; National Association for Sport and Physical Education [NASPE], 2010). Those FMS allow children to function effectively and independently in their daily life and provide the foundation for cognitive, social, and physical growth (Castetbon & Andreyeva, 2012; Logan et al., 2012).

Research recognized that the impairment in FMS developmental functioning is associated with obesity in early childhood (D'Hondt et al., 2013). In addition, a low socioeconomic status (SES) is also suggested as an environmental risk factor for FMS development (Shrewsbury & Wardle, 2008) and a significant determinant of obesity (Castetbon & Andreyeva, 2012). The national standards and grade-level outcomes for elementary schools focus on fostering the maturation of the FMS and developing the understanding of movement concepts (SHAPE America, 2014). Thus, the kindergarten year emerges as a critical year for young children's skill acquisition and future FMS development (Logan et al., 2012).

Recently, Stodden and his colleagues (2008) developed a conceptual model in which a developmental dynamic relation between obesity and the behavioral factors (FMS, PA, and physical fitness) within the model is proposed. This conceptual model asserts that children with less-developed FMS will be drawn into a negative spiral of disengagement. Consequently, these less-developed/skilled individuals might demonstrate low levels of PA and run a greater risk of being obese during later childhood, adolescence, and adulthood (Stodden et al., 2008).

Although the association between FMS, PA, and body composition such as BMI in children and adolescents was supported by growing evidence (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014; D'Hondt et al., 2013; Williams et al., 2008), the data in kindergarteners is limited and remains unclear in the current pediatric literature. For example, Williams et al. (2008) found that children with better-developed FMS spent more time in both MVPA and VPA than children with less-developed FMS in the preschool population (3–4 years old). However, one most recent study (Spessato, Gabbard, & Valentini, 2013) found that children's FMS competency was not significantly associated with both PA and BMI in the 5–7 years old groups. A recent longitudinal study (Lopes, Rodrigues, Maia, & Malina, 2011) provided the primary evidence regarding the directional relation between FMS and PA. Specifically, they found that FMS was the only significant predictor of changes in PA independent of BMI among children (6–10 years), whereas, BMI and skinfolds did not contribute significant variance to changes in PA and FMS over time.

The theoretical model proposed by Stodden and colleagues (2008) has not been thoroughly tested and the data in kindergarten students lacks consistent findings in the current literature (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011). Based on Stodden et al. (2008) model, the development of FMS may be a causal mechanism to promote PA during childhood, and this relation may explain why school-aged children are not active enough and become sedentary later in life. Given the notion that children from low income families spend more time in sedentary behavior and fewer time in PA (Tandon et al., 2012), it is of special relevance to public health to better understand how this FMS-PA association may influence SB among young children, especially those from socioeconomically disadvantaged families.

While previous studies have not provided a clear picture /systematic approach to this effort, theoretical based investigations are needed in order to identify behavioral mechanisms of obesity in early childhood (Cohen et al., 2014; Stodden et al., 2008). Guided by Stodden and his colleagues' conceptual model (Stodden et al., 2008), the purpose of this study was to examine and further define the relations among FMS (locomotor, objective control, and FMS index), SB and different intensity levels of physical activity (light PA [LPA], moderate-to-vigorous PA [MVPA], and vigorous PA [VPA]) among kindergarten children from socioeconomically disadvantaged families.

Methods

Participants and procedures

Participants (N = 256 kindergarteners: 129 boys and 127 girls) were recruited from three public primary schools in the southern United States. All participants (M_{age} = 5.37, SD = .48) were classified as socioeconomically disadvantaged based on the Income Eligibility Guidelines (IECGs; Start & Assistance, 2012) used to determine eligibility for free (91.1%) or reduced cost lunch (8.9%). Approval to conduct the study was received from the University Institutional Review Board, and the permission to collect data was granted, and the teachers before the start of the study. Additionally, parental informed consent forms were obtained prior to starting the study. All three schools used the same federal guidelines of the inclusion criteria for participants (Individuals With Disabilities Education Act of 2004 [IDEA], 2004). All children were included in the study after receiving the signed parental consent (total N = 313), and fifty-seven were excluded in the data analyses because they were not qualify for the free/reduced cost lunch program.

A prospective design was used in this study across an academic year. Specifically, we adopted a two-wave design and assessments were arranged based on the temporal precedence of associations specified within the hypothesized model: Time 1 = FMS, Time 2 = BMI, MVPA and SB). In addition, this conceptual reasoning of the design is also consistent with the past work (Stodden et al., 2008). During the first wave of data collection (Time 1; 2013 Fall) children's FMS including dribbling with hand, underhand throwing, sliding, and hopping (National Association for Sport and Physical Education, 2010) were assessed. At Time 2 (2014 Spring) children's height and weight were measured before assessing accelerometer-based PA and SB over five consecutive school-days.

Measures

Demographic information

Participants' demographic information including gender, age, ethnicity, meal code (free, reduced, and paid lunch program) were reported by the schools.

Fundamental motor skills

PE Metrics™ was used to measure students' FMS including dribbling with hand, underhand throwing, sliding, and hopping (kindergarten-level; National Association for Sport and Physical Education, 2010). All motor skill assessments were scored by two well-trained research assistants. The performance of each skill was scored based on four competence-level scoring rubric (*4 = Consistently; 3 = Usually; 2 = Sometimes; 1 = Seldom*). Children were provided the instructions of each skill and observed the demonstration of each skill before being asked to perform. For dribbling, each child was asked to continuously dribble a ball for 15 s with one hand in a 3ft × 3ft square. Each child performed hopping in place for 10 s on each foot in a 3ft × 3ft square. For sliding, children were asked to slide continuously for 30 feet with the preferred foot leading. The *form* and *consistency of action* of the performance for dribbling, hopping, and sliding were scored separately based on the four-level scoring rubric. The total score for each skill ranged from 0 to 8. For underhand throwing, each child was asked to perform three trials by sending a whiffle ball forward through the air to a 10ft × 10ft target (3 feet off the floor) on the wall. The distance between the throwing line and the target was 15 feet, and the 10 feet from the throwing line was also marked as the minimal airborne distance of the performance. The *form* and *distance/boundaries* of the performance were scored based on the four-level scoring rubric. The total score was the sum of three trails and ranged from 0 to 24. Data used in the analyses were the composite score for each category: locomotor (sliding and hopping), objective control (underhand throwing and dribbling with hand), and FMS index (total motor scores; values range from 0 to 48). The PE Metrics ™ is a valid and reliable national standards-based assessment tool for measuring children's FMS developed/tested by NASPE's assessment Task Force (Dyson et al., 2011; Intraclass correlation (ICC) = .79).

Body mass index

Health-O-Meter® Digital Scale was used to measure children's height and weight (without shoes). The measurement station was set up in a room provided by the schools. During the test, researcher measured one child at a time in the room and others were waiting in a line outside of the measurement room. Each child was asked to take off shoes before stepping on the scale, with the feet together and head straightened in a neutral position. Height was recorded to the nearest 0.1 cm. Weight was measured in minimal clothing and to the nearest 0.1 kg. BMI was calculated as weights divided by the square of the height and expressed as kg/m^2.

Physical activity and sedentary behaviors

To objectively measure children's different intensity levels of PA (including LPA, MVPA, and VPA) and sedentary behavior (SB) during school, Actical activity monitors (accelerometers; Mini-Mitter Co., Inc., Bend, OR) were utilized for five consecutive school days. The Actical accelerometry-based activity monitor has been established as a reliable and valid tool for

measuring PA in children (John & Freedson, 2012). Participants wore accelerometers on an elastic wrist band on their non-dominant hands for five consecutive days during school time. Accelerometers were initialized to save data in 60-s intervals to detect spontaneous PA of children. Raw total minutes of SB, LPA, MVPA and VPA were monitored and recorded by the accelerometers. Each child's average time spent in SB, LPA, MVPA, and VPA in five school-days were calculated and converted to the standardized residual scores labeled as RSB, RLPA, RMVA and RVPA (Mean = 0, SD = 1) before the data analysis.

Statistical analyses

After screening the raw data to assure accuracy and normality, three steps were taken to analyze the data in this study using SPSS 22. First, descriptive statistics were calculated for all study variables. (ICC) was used to estimate the reliability of five days accelerometer measurement and FMS measurement which provides estimates of systematic and error variance (Thomas, Nelson, & Silverman, 2015). All the variables including locomotor, object control, FMS, BMI, LPA, VPA, MVPA, and SB were continuous variables. The demographic variables including gender, age, ethnicity, meal code were categorical variables.

Then, Pearson product-moment correlations was used to examine the bivariate correlations between FMS (locomotor, objective control, and FMS index), BMI, and average time spent in PA intensity levels (using RLPA, RMVPA, and RVPA in the analysis), and SB (using RSB in the analysis) for the total group. Second, to understand the second research question, three multiple regression analyses were conducted to test the predictive utilities of both locomotor and objective control skills on LPA, MVPA, and VPA after controlling for BMI, respectively.

Finally, in order to answer the last research question, product of coefficients (MacKinnon, Krull, & Lockwood, 2000) approach to statistical mediation analysis was used to define how FMS index (total motor skill; independent variable) may interact with MVPA (mediator) to influence children's SB (dependent variable) during school. To construct 95% confidence limits for testing significantly mediated or indirect effect, the product of coefficients $\hat{a}$, $\hat{b}$, $\hat{a}\hat{b}$, and the standard error of $\hat{a}\hat{b}$ were calculated based on essential steps of equation 2 and 3 (Path a and b; Cerin & MacKinnon, 2009; MacKinnon, Fairchild, & Fritz, 2007). An alpha level of .05 was used for all statistical analyses.

Results

The descriptive analysis results were reported in Table 1. The intraclass correlations (ICC; Thomas et al., 2015) were calculated indicating FMS and MVPA measures were reliable with ICCs equal to .79 and .84, respectively. The majority of the participants (52%) were Hispanic and the remainder included White (24.6%), Black (21.5%), Asian-American (0.4%), and others (1.6%). It appears that most children who are disadvantaged are Hispanic in this study. On average, within total 5–6 school-hours, children spent ~ 3% of the time engaging in SB, most of the time (~67%) in LPA, ~23% of the time in MVPA. Pearson's bivariate correlations (Table 2) revealed that all FMS variables (locomotor, object control skills, and FMS index) were significantly associated with three different levels of PA (LPA, MVPA, and VPA) and SB. SB was positively related to LPA, but have a negative relation with MVPA and VPA. In addition, total motor skills score (FMS index) had a negative relation with time spent in SB and LPA, but were positively related to MVPA and VPA.

Table 1. Descriptive statistics (***N*** = 256).

Variables	*N*	Mean	SD
1. Age	5 years old = 162 6 years old = 94	5.37	.48
2. Gender	Boys = 129 Girls = 127		
3. Ethnicity	Hispanic = 133 White = 63 Black = 55 Others = 6		
4. Meal code	Free lunch = 214 Reduced lunch = 42		
5. Locomotor Skill		11.77	3.03
6. Object Control Skill		19.53	4.66
7. FMS Index		31.44	6.33
8. BMI Percentile		59.90	30.12
9. %LPA		67.44	10.38
10. %VPA		3.39	3.40
11. %MVPA		23.49	14.41
12. %SED		2.70	2.80

Note. M = Mean; SD = Standard Deviation; %LPA = Percent time spend in light PA; %VPA = Percent time spend in Vigorous PA; %MVPA = Percent time spend in moderate to vigorous PA; %SED = Percent time spend in sedentary behavior.

Table 2. Correlations among the study variables (***N*** = 256).

Measure	1	2	3	4	5	6	7	8
1. Locomotor Skill	(1)							
2. Object Control Skill	.39**	(1)						
3. FMS Index	.74**	.91**	(1)					
4. *z*-BMI	.11	.09	.15*	(1)				
5. RLPA	−.18**	−.18**	−.23**	−.01	(1)			
6. RVPA	.18**	.18**	.22**	.01	−.64**	(1)		
7. RMVPA	.21**	.21**	.26**	−.01	−.93**	.80**	(1)	
8. RSB	−.13*	−.16*	−.19**	−.02	.17**	−.15*	−.32**	(1)

Note. Cronbach alpha coefficients are provided along the diagonal for motor skill measures (Intraclass correlation). Different intensity levels of physical activity (PA) including LPA, VPA, and MVPA are all residual-scores in this table. Specifically, RLPA = Residual scores of light PA; RVPA = Residual scores of Vigorous PA; RMVPA = Residual scores of moderate to vigorous PA; RSED = Residual scores of sedentary behavior.
*$p < .05$; **$p < .01$.

The examination of linear relationship among the independent variables suggested that the assumption of no multicollinearity was met; the VIF and Tolerance statistics for the independent variables involved were all close to one and greater than .20, respectively. Casewise diagnostics for the three multiple regression models tested showed that the absolute values of DfBetas for the predictors did not exceed one; no more than 5% cases of the standardized residuals had absolute values greater than two (1, 0.3, and 0.3% for regression models 1, 2, and 3, respectively); no cases of Cook's distance were greater than one; and no cases of the leverage values exceeded three times the average leverage. Regression analyses (Table 3) indicated that only locomotor skills but not object control skills explained significant variance to children's LPA, MVPA, and VPA, after controlling for BMI.

Tests of mediation effects

A series of regression analyses were conducted to determine if MVPA mediates the relation between FMS (FMS index) and sedentary behavior (SB). The mediation model was presented in Figure 1. In the path *c*, FMS index was a significant predictor of SB [F (1, 255)

Table 3. Results of multiple regressions (***N*** = 256).

Dependent variables	Independent variables	*B*	SE *B*	R^2	*β*	*T*-value
RLPA	z-BMI	.10	.07	6.4%	.09	1.41
	Locomotor Skill	−.06	.03		−.19	−2.62**
	Object Control Skill	−.02	.02		−.11	−1.59
RVPA	z-BMI	−.06	.08		−.05	−.79
	Locomotor Skill	.06	.03	5.3%	.16	2.242*
	Object Control Skill	.03	.02		.12	1.65
RMVPA	z-BMI	−.10	.08	7.9%	−.09	−1.34
	Locomotor Skill	.07	.03		.20	2.84**
	Object Control Skill	.03	.02		.14	1.93

Notes. B values are unstandardized regression coefficients; SE B values are the standard errors for unstandardized regression coefficients; R^2 values are cumulative, with each incremental step adding to the variance explained; *β* values are standardized regression coefficients from the final stage of the regression analysis.
*$p < .05$; **$p < .01$.

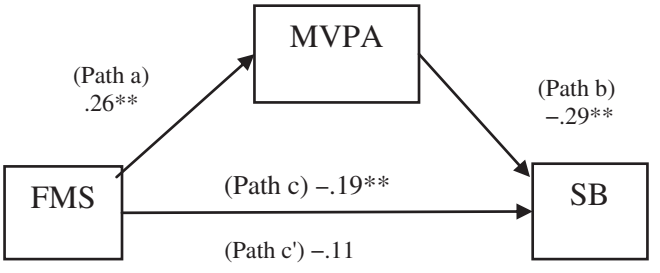

Figure 1. Mediation model of association between FMS and SB through MVPA (mediator). *Notes*. FMS = Fundamental Motor Skill; SB = Sedentary Behavior; and MVPA = Moderator to Vigorous Physical Activity. * $p < .05$; ** $p < .01$.

= 8.64, $p < .005$], explaining 3.6% of the variance (total effect *c*: $\beta_c = -.19$, $p < .005$). In the path *b*, the effect of the FMS on the SB became non-significant after taking into account the effect of MVPA (mediator; direct effect *c*′: $\beta_{c'} = -.11$, $p = .08$), thus, the MVPA was the only significant predictor in the model ($\beta_b = -.29$, $p < .001$; $R^2 = 11\%$). In the path *a*, total motor skill (FMS index) was a significant predictor of children's MVPA [F (1, 255) = 16.22, $p < .001$], explaining 6.7% of the variance ($\beta_a = .26$, $p < .001$). In the mediation context, if the effect of the independent variable (FMS) on the dependent variable (SB) is no longer significant when the mediator (MVPA) is controlled, the finding supports full mediation (MacKinnon et al., 2007). According to the product of coefficients approach (MacKinnon et al., 2007), the significant indirect effect of MVPA on the relation between FMS and SB was supported (95% CI: [–0.019, –0.006]), and the ratio of the indirect effect to the total effect is .40 (effect size; Preacher & Kelley, 2011). Thus, our data support the contention that the relation between FMS and children's SB was fully mediated by MVPA.

Discussion

Knowledge of the association between FMS and different intensity levels of PA could provide important information for understanding variations in the development of young children and their healthy behaviors in the early school years (Williams et al., 2008). Researchers suggest that the relation between FMS and PA is important to the health of children (D'Hondt

et al., 2013) and FMS should be a key component of early childhood education programs (Cohen et al., 2014). The findings of this study indicate that lacks of FMS competency may be a reason of why young children spend more time in light intensity levels of activities, as well as being sedentary even in early childhood. Skillful children are more likely to participant in moderate to vigorous activities but not light intensity activities during the school day.

Although children in our study spent more than 60 min of MVPA (*Mean* = 95.3, SD = 52.8) during school, most of the school time children were involved in sedentary to LPA behaviors (70%). According to previous research evidence that PA should be of at least a moderate intensity in order to achieve substantive health benefits, especially in high-risk youngsters (Janssen & LeBlanc, 2010). For example, research proposed that children from socioeconomically disadvantaged Australian family are less active and demonstrate fewer competencies in FMS which may increase the risk of obesity in the future (Cohen et al., 2014). The major contribution of our study was to explore the dose-specific relations between PA and FMS in socioeconomically disadvantaged kindergarteners in U.S. The results have potential implications for children's early elementary experiences as the function of FMS on children's PA levels, although a weak association between FMS and PA was found in this study. In addition, evidence from our study supports and expands the small but growing body of evidence that FMS may be an important factor in promoting a physically active lifestyle in socioeconomically disadvantaged children (Cohen et al., 2014).

This study found locomotor skills (hopping and sliding) but not object control skills (dribbling and underhand throwing) explained a significant amount of variance in children's LPA, MVPA, and VPA during school. These data suggest that during kindergarten year, children who are skilled in hopping and sliding might be most likely to participate in MVPA during school. Consistent with previous research in older children that individual who engaged in more MVPA was more competent at locomotor skills (Cohen et al., 2014). On the basis of these results, the current SHAPE America (2014) recommendation of grade-level skill acquisition for continued participation in PA was supported in our study.

Mediational Effects of the MVPA

The significant mediation or indirect effect of MVPA on the relation between FMS and SB further supports the tenets of the Stodden et al.'s developmental model. The current work extends this to the investigation of how FMS performance associated with kindergarten children's PA and SB in early school year. Although FMS had a weak relation with both MVPA (r = .26) and SB (r = –.19), however, a moderate relation between MVPA and SB (r = –.32) was found which supports our mediation hypothesis. This suggests that developing FMS competency is an important approach to influence obesity-related behaviors such as PA and SB as earlier as the kindergarten year. Furthermore, this study provides primary evidence to support Stodden et al. (2008) conceptual model that PA can be directed towards skill acquisition, which is an essential element needed in school endeavors for fighting childhood obesity in early childhood. This observation also provides valuable insights regarding how to promote children's PA and prevent SB during school, and suggests that development of FMS may be considered as an important intervention approach in socioeconomically disadvantaged kindergarteners. Future longitudinal and intervention studies are needed to determine the nature of the impact of FMS on the different intensity levels of PA.

Research including assessment of theory-based mediators and PA is also warranted (Ryan, Patrick, Deci, & Williams, 2008) from a public health perspective, recognizing the importance of these behavioral mediators of obese-related outcomes. The support of mediation effects reinforces the notions that (a) the Stodden et al.'s developmental model (2008) is a viable framework to understand the behavioral mechanisms of childhood obesity during early school year, and (b) the dynamic interaction between FMS and PA proposed by the Stodden's developmental model (2008) may have implications for understanding the likelihood of future SB in the pediatric population.

Conclusions

This study makes a unique contribution to the literature by showing how FMS and PA interacted together to influence SB of young children from socioeconomically disadvantaged families during school. We argue that physical education teachers, in general, are aware of the importance of fostering FMS development among children of all abilities (SHAPE America, 2014). Specifically, school physical education curricula or PA program in kindergarten year that emphasize the development of FMS may help children develop sufficient knowledge, attitudes, skills, and competence. This can ultimately foster the adoption and maintenance of physically active lifestyles, as well as reduce the risk of being sedentary. Although other psychosocial factors clearly have the potential to affect children's obesity-related behaviors in school (Gu & Solmon, 2015), a paucity of work has explored how behavioral process proposed by Stodden et al. (2008) may influence children's risk behaviors such as SB. Our study provided evidence on this issue, and although this is a good beginning, additional study is needed to refute or replicate our findings.

The findings from the study must be considered within the context of inherent limitations. Although the dynamic relation related to FMS and PA in this study was specifically aligned with Stodden et al. (2008) model, future research using longitudinal and experimental designs would provide a clear picture of the causality for those hypothesized associations. The exclusion of potential influential variables such as age, gender and ethnicity in the analyses was also a limitation of this study. Furthermore, despite the relative advantages of using objective measures of FMS and PA in this study, the valid and reliable of measurement of behaviors in young children remain challenging. To conclude, these findings suggest that effective public health approaches to promote PA and prevent sedentary behavior in early childhood should emphasize the role of FMS learning among the socioeconomically disadvantaged children, characterized as a key modifiable determinant of PA and childhood obesity.

Disclosure statement

No potential conflict of interest was reported by the author.

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