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Associations of School Day Sedentary Behavior and Physical Activity With Gross Motor Skills: Use of Compositional Data Analysis

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Background: To examine the relationships among school day sedentary times (SED), light physical activity (LPA), and moderate to vigorous physical activity (MVPA) with gross motor skills in children using Compositional Data Analysis. **Methods**: Participants were 409 children (mean age = 8.4 [1.8] y) recruited across 5 low-income schools. Gross motor skills were assessed using the test for gross motor development—third edition (TGMD-3), and physical activity was assessed using accelerometers. Isometric log-ratio coordinates were calculated by quantifying the relative proportion of percentage of the school day spent in SED, LPA, and MVPA. The associations of the isometric log-ratio coordinates with the TGMD-3 scores were estimated using general linear mixed-effects models adjusted for age, body mass index, estimated aerobic capacity, and school affiliation. **Results**: A higher proportion of the school day spent in %MVPA relative to %SED and %LPA was significantly associated with higher TGMD-3 total scores ($\gamma_{MVPA} = 14.44$, $P = .01$). This relationship was also observed for the ball skills subtest scores ($\gamma_{MVPA} = 16.12$, $P = .003$). **Conclusions**: Replacing %SED and %LPA with %MVPA during school hours may be an effective strategy for improving gross motor skills, specifically ball skills, in low-income elementary school-aged children.

Keywords: accelerometry, biostatistics, measurement, motor behavior, youth

Fundamental gross motor skills facilitate physical health, well-being, and performance in activities of daily living for the developing child.[1,2] Fundamental gross motor skills manifest from rudimentary phases of infancy to complicated locomotor and manipulative movements and serve as building blocks for complex movements.[3] Fundamental gross motor skills may help children to control their bodies, manipulate their environment, and form complex skills involved in sports and recreational activities.[4] Therefore, optimal development of these skills is important for children and may facilitate participation in daily physical activity, which has its own benefits including decreased risk for noncommunicable cardiometabolic disease, in addition to facilitating cognitive and emotional development.[5–7]

Recent research has established a link between gross motor skills and physical activity in children and adolescents.[8,9] This relationship has been observed in both cross-sectional and longitudinal research and may be partially mediated through motivational constructs.[10–12] Some researchers have postulated that the relationship between gross motor skills and physical activity is bidirectional,[12] which is important when devising school and community-based interventions.[13] The aforementioned relationships have manifested various conceptual frameworks linking physical activity, gross motor skills, and various health outcomes. Stodden et al[9] proposed a conceptual framework linking improvements in gross motor skills with increases in physical activity in children and adolescents, which will further lead to decreases in the risk of cardiometabolic disease. These relationships have been empirically tested and may be partially mediated through aerobic fitness and perceived motor competence.[13,14]

Analyses used in past research linking gross motor skills with physical activity, specifically moderate to vigorous physical activity (MVPA), has assumed independence of this construct with other behavioral compositional parts, such as sedentary times (SED) and light physical activity (LPA). Whether physical activity is assessed during the entire day (24 h) or during school hours (7 h), changes in MVPA will inherently affect time spent in SED and LPA because of the time-constrained nature of assessment.[15] Traditional methods of analyzing physical activity data may not effectively address the codependence among SED, LPA, and MVPA.[15]

A novel analytic approach, Compositional Data Analysis (CoDa), has recently been used to analyze physical activity data.[16,17] CoDa assumes codependence among physical activity compositional parts within a time-constrained data analytic framework, which makes it appropriate for assessing school day physical activity.[18,19] Using CoDa, researchers and practitioners can understand if the relative proportion of school day MVPA in relation to SED and LPA, in addition to other relative proportions among the compositional parts, significantly relates to gross motor skills, rather than employing the traditional approach where respective physical activity compositions are analyzed independently. No study to date has examined the relationships between physical activity and gross motor skills in a sample of children using CoDa. Doing so will provide information regarding the predictive utility among relative proportions of physical activity compositional parts with gross motor skills, which will be helpful when devising future school and community-based interventions. Therefore, the purpose of this study was to examine the relationships of school day SED, LPA, and MVPA with gross motor skills in children using CoDa.

Methods

Participants

Participants were 435 school-aged children (grades: first to fifth; aged: 8.4 [1.8] y; 204 girls, 205 boys) recruited from 5 Title I elementary schools from the Mountain West region of the United States. After deleting missing data (n = 26), a total of 409 children

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(94% of total sample) were included. Both socioeconomic status and ethnicity data were collected at the school level. One hundred and three students were recruited from school 1 (91% low income; 88% ethnic minority), 92 students were recruited from school 2 (95% low income; 78% ethnic minority), 103 students were recruited from school 3 (96% low income; 91% ethnic minority), 65 students were recruited from school 4 (95% low income; 85% ethnic minority), and 46 students were recruited from school 5 (92% low income; 81% ethnic minority). Ninety-five students were recruited from the first grade, 95 students were recruited from second grade, 84 students were recruited from third grade, 69 students were recruited from fourth grade, and 66 students were recruited from fifth grade. Written assent was obtained from the students, and consent was obtained from the parents prior to data collection. The University of Utah institutional review board approved the protocols employed in this study.

Physical Activity Assessment

Physical activity was assessed using ActiGraph triaxial accelerometers (wGT3X-BT; Pensacola, FL). Children were instructed to wear the accelerometers for 5 consecutive school days (Monday through Friday) between the hours of 8 AM and 3 PM (7 h). The device was worn on the waist at the level of the iliac crest aligned with the right kneecap. Classroom teachers, physical educators, and members of the research team ensured that the devices were worn during the entirety of the school day. Valid data were determined by at least 3 total wear days with at least 6 hours of wear time per day. Accelerometer data were recorded in 15-second epochs at 100 Hz and processed using the cut points by Evenson et al,[20] which was calibrated against indirect calorimetry.[21] The epochs during the school day were categorized as sedentary, light, moderate, or vigorous physical activity. The moderate and vigorous physical activity classifiers were aggregated for time in MVPA. Wear time validation was employed using the Choi et al[22] algorithm. The ActiLife 6.11.5 software program (ActiGraph Corp, Pensacola, FL) was used to initialize, download, process, and store accelerometer data.

Health-Related Fitness Assessment

Body mass index (BMI) was calculated by dividing students' weight in kilograms by the square of their height in meters (kg/m^2). Height was measured to the nearest 0.01 m using a portable stadiometer (model 213; Seca, Hanover, MD), and weight was measured to the nearest 0.1 kg using a portable medical scale (BD-590; Tanita, Tokyo, Japan). Height and weight were collected in a private room during each student's physical education class, and shoes were off for all measurements.

Estimated aerobic capacity (VO_2peak) was assessed using the 20-m Progressive Aerobic Cardiovascular Endurance Run administered during each child's physical education class.[23] The Progressive Aerobic Cardiovascular Endurance Run was conducted on a marked gymnasium floor with background music provided by a compact disk. Each student was instructed to run from one floor marker to another floor marker across a 20-m distance within an allotted time frame. The allotted time given to reach the specified distance incrementally shortened as the test progressed. If the student failed twice to reach the other floor marker, the test was terminated. The final score was recorded in laps. Estimated VO_2peak was calculated using a validated prediction algorithm that recorded Progressive Aerobic Cardiovascular Endurance Run laps and age.[24]

Gross Motor Skill Assessment

The test for gross motor development—third edition (TGMD-3) was the instrument used to assess gross motor skills. Psychometric properties of the TGMD-3 have been recently reported with high levels of reliability and validity.[25,26] The TGMD-3 assesses gross motor competency across 13 movement skills within separate locomotor and ball skills subtests. The total score for the locomotor subtest is 46, and the total score for the balls skill subtest is 54. Locomotor skill test items consisted of running, galloping, hopping, skipping, horizontal jumping, and sliding. Ball skill test items consisted of 2-handed and 1-handed striking, dribbling, overhand throwing, underhand throwing, catching, and kicking. Each student performed the test items across 2 trials that were each scored based on 3 to 5 specific performance criteria (0 = did not perform correctly; 1 = performed correctly). Data used for analysis were the locomotor subtest scores, the ball skills subtest scores, and a gross motor test scores (locomotor subtest score + ball skill subtest score = TGMD-3). One member of the research team collected locomotor information at each school, and one member of the research team collected ball skill information at each school to maintain testing consistency. Intraobserver and interobserver reliability were tested on a third-grade class. The intraclass correlation coefficient = .91 for intraobserver agreement and intraclass correlation coefficient = .90 for interobserver agreement, which were both considered acceptable.

Procedures

Physical activity, gross motor skills, and health-related fitness were assessed during separate weeks at each school. No longer than 2 weeks separated assessment between any 2 of the observed constructs. Testing order was counterbalanced at the school level to attenuate potential for testing order confounding.

Isometric Log Ratios. The following procedures regarding CoDa methodology have been adopted from prior published work.[15–19] Minutes in SED, LPA, and MVPA were converted to percentage of wear time in each respective compositional part so that the sum is equal to 100%. This was done by computing the geometric mean (in minutes) for each part and then adjusting the parts so that they add to 420 minutes (equal to 7-h school day). Therefore, the percentage wear time value represents time use out of a 7-hour school day. Compositional data occupy a quotient space which, in the context of the current study, can be represented in a D-part simplex with 3 compositional parts (3-part simplex).[18] However, in order to analyze the data in real space, log-ratio data transformations need to be performed. Isometric log-ratio coordinates (ILRs) were calculated using the following equations:

$$\text{ILR1} = \sqrt{\frac{2}{3}} \ln\left(\frac{\%\text{SED}}{(\%\text{LPA} \times \%\text{MVPA})^{\frac{1}{2}}}\right), \quad (1)$$

$$\text{ILR2} = \sqrt{1/2} \ln\left(\frac{\%\text{LPA}}{\%\text{MVPA}}\right). \quad (2)$$

ILR1 expresses %SED to time in all other non-SED behaviors, and ILR2 is the ratio of %LPA in relation to %MVPA. These 2 ILRs were included in the general linear models described below with corresponding parameter estimates (γ). However, because only ILR1 is interpretable (corresponding to γ_{SED}), additional

ILRs were calculated within a sequential permutation procedure to obtain interpretable parameter estimates for %LPA (ILR3 and ILR4) and %MVPA (ILR5 and ILR6).[19]

$$\text{ILR3} = \sqrt{\frac{2}{3}}\ln\left(\frac{\%\text{LPA}}{(\%\text{SED}\times\%\text{MVPA})^{\frac{1}{2}}}\right), \quad (3)$$

$$\text{ILR4} = \sqrt{1/2}\ln\left(\frac{\%\text{SED}}{\%\text{MVPA}}\right), \quad (4)$$

$$\text{ILR5} = \sqrt{\frac{2}{3}}\ln\left(\frac{\%\text{MVPA}}{(\%\text{SED}\times\%\text{LPA})^{\frac{1}{2}}}\right), \quad (5)$$

$$\text{ILR6} = \sqrt{1/2}\ln\left(\frac{\%\text{SED}}{\%\text{LPA}}\right). \quad (6)$$

Therefore, ILR1 and ILR2 were entered into the first permutation of each linear model to obtain the parameter estimate γ_{SED}, ILR3 and ILR4 were entered into the second permutation of each linear model to obtain the parameter estimate γ_{LPA}, and ILR5 and ILR6 were entered into the third permutation of each linear model to obtain the parameter estimate γ_{MVPA}. Because of the permutation principle, each respective model with 3 compositional parts (%SED, %LPA, and %MVPA) will have the same estimated fit, intercept, and *P* value for all covariates per permutation.[19] This sequential permutation was carried out using the modeling procedures described below.

Statistical Analysis. Mean differences between sexes on covariates were tested using independent *t* tests. Arithmetic and geometric means for the physical activity compositional parts were reported. A compositional mean bar plot was created to display geometric means for each sex with the mean of the whole group under the CoDa approach.[16] Because standard measures of dispersion (ie, SD, SE) are less meaningful under CoDa, a compositional variation matrix was used to communicate the variation of the calculated pairwise log ratios (eg, ln(%SED/%MVPA)), which itself is a meaningful estimation of the relative dispersion structure.[19] If the variation coefficients from this matrix approach 0, then there is high proportionality between 2 respective compositional parts. High proportionality suggests that there is a strong relationship/codependence between respective compositional parts.[19] However, if the coefficients are large within the variation matrix, then there is low proportionality between compositional parts.[19] Total variance was calculated by taking the sum of the variances on either side of the diagonal divided by 3.[15]

To examine the relationship among %SED, %LPA, %MVPA, and gross motor skills under CoDa, multilevel general linear mixed-effects models were employed with random intercepts on the classroom level to adjust for clustering within the data structure (students clustered within classrooms). Separate models were employed on the locomotor subtest scores, the ball skills subtest scores, and the total TGMD-3 scores. Likelihood ratio tests were used to test the utility of each multilevel model against the naïve model assuming no clustering within the data structure. Fixed effects included the ILR predictors (calculated using the procedures outlined in the previous section) with age, BMI, estimated VO_2peak, and school affiliation as included covariates.

Sequential permutation was used on each model to obtain interpretable parameter estimates for each compositional part. Again, because standard measures of variability are meaningless using CoDa,[19] only the parameter estimates (γ) and *P* values were reported.

Because parameter estimates for ILRs are difficult to interpret in the context of units of change in the raw behaviors,[18,19] a change prediction matrix, recommended by Chastin et al,[19] was derived to communicate the relative effect of change in the ratio between any 2 physical activity compositional parts and adjusted variation in TGMD-3 scores. Data from this matrix were used to derive a plot communicating how a 5% substitution in the ratio between any 2 compositional parts, with a fixed relative amount of the third compositional part, associates with predicted TGMD-3 score change. Technical details of this specific CoDa calculation have been described elsewhere.[19] All analyses had an alpha level set at $P < .05$ and were carried out using Stata version 15.0 statistical software package (StataCorp LLC, College Station, TX).

Results

The descriptive statistics for the total sample and within sex groups are communicated in Table 1. There were no statistically significant differences between sexes on age, BMI, or estimated VO_2peak. Table 2 communicates the arithmetic and geometric means for %SED, %LPA, and %MVPA. As expected, the majority of the school day was spent in %SED, followed by %LPA and %MVPA. Table 3 communicates the compositional variation matrix. Coefficients within the variation matrix were small, indicating a high degree of proportionality/codependence between compositional parts. The highest coefficient was the variation in the ratio between %SED and %MVPA, and the smallest was the variation in the ratio between %LPA and %MVPA. Descriptive differences comparing

Table 1 Participants' Descriptive Characteristics on the Included Covariates (Arithmetic Means and SDs)

	Total sample (N = 409)	Girls (n = 204)	Boys (n = 205)
Age, y	8.4 (1.8)	8.4 (1.8)	8.4 (1.8)
Body mass index, kg/m^2	17.7 (5.3)	17.4 (4.0)	18.1 (6.4)
Estimated aerobic capacity, mL/kg/min	46.6 (5.7)	46.2 (5.7)	47.0 (5.7)

Table 2 Arithmetic and Geometric Compositional Means for the 3 Physical Activity Compositional Parts (in Minutes and Percentage of School Day)

	Arithmetic mean		Compositional mean	
	Min/d	%	Min/d	%
SED	280.6	66.8	281.5	67.0
LPA	113.8	27.1	113.0	26.9
MVPA	27.3	6.5	25.6	6.1

Abbreviations: LPA, light physical activity; MVPA, moderate to vigorous physical activity; SED, sedentary times.

Table 3 Compositional Variation Matrix

	%SED	%LPA	%MVPA
%SED	0	−0.15	−0.22
%LPA	0.15	0	−0.11
%MVPA	0.22	0.11	0

Abbreviations: LPA, light physical activity; MVPA, moderate to vigorous physical activity; SED, sedentary times.

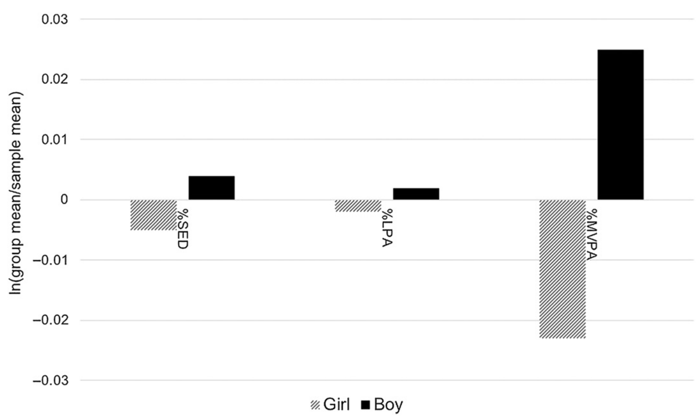

Figure 1 — Compositional geometric mean bar plot stratified by sex. Note: Positive and negative bars reflect relative compositional geometric mean values of a part above and below the overall mean composition, respectively. This graphical representation is useful to investigate the relative physical activity profiles between sexes. Each bar is a component of ln(cen0i/cen0), where cen0i is the compositional geometric sex group mean and cen0 is the compositional geometric sample mean, per compositional part. LPA indicates light physical activity; MVPA, moderate to vigorous physical activity; SED, sedentary times.

geometric means for each sex with the mean of the entire sample under the CoDa approach are presented in Figure 1. Differences were observed for each compositional part with boys being more active and less sedentary than girls. The greatest differences between sexes were in %MVPA.

Table 4 presents the parameter estimates from the general linear mixed-effects models under the CoDA approach. For both ball skills and the total TGMD-3 outcomes, a higher proportion of the school day spent in %LPA relative to %MVPA was significantly related to lower motor skill scores, and a higher proportion of the school day spent in %MVPA relative to %LPA was significantly related to higher motor skill scores ($P < .05$). For the locomotor skills outcome, there were no statistically significant ILRs. Likelihood ratio tests from each model were statistically significant ($P < .001$), indicating the appropriateness of multilevel modeling.

A change matrix is presented in Table 5 for the total TGMD-3 scores, communicating how a change in the ratio in the compositional parts would associate with change in TGMD-3 scores. If a coefficient in Table 5 is positive, then scores in the TGMD-3 would increase if the row composition is increased in relation to the column composition; if a coefficient in Table 5 is negative, then scores in TGMD-3 would decrease if the row composition is increased relative to the column composition. Therefore, from the coefficients calculated and presented in Table 5, increases in %MVPA relative to %LPA and increases in %MVPA relative to %SED would associate with higher TGMD-3 scores. These

Table 4 Parameter Estimates From General Linear Mixed-Effects Models Under CoDa

Outcome	Predictor	γ Coefficient	*P* value
Locomotor subtest score	%SED	−9.07	.39
	%LPA	8.10	.55
	%MVPA	9.08	.46
	Age, y	4.13	<.001*
	BMI, kg/m^2	0.04	.69
	Estimated VO_2peak, mL/kg/min	0.47	<.001*
	School 2	0.56	.23
	School 3	1.55	.002*
	School 4	0.97	.11
	School 5	1.03	.24
Ball skills subtest score	%SED	2.09	.61
	%LPA	−18.16	.02*
	%MVPA	16.12	.003*
	Age, y	1.65	<.001*
	BMI, kg/m^2	0.03	.58
	Estimated VO_2peak, mL/kg/min	0.20	.01*
	School 2	0.83	.05
	School 3	1.23	.004*
	School 4	0.99	.11
	School 5	1.09	.08
TGMD-3 total score	%SED	5.05	.26
	%LPA	−19.64	.02*
	%MVPA	14.44	.01*
	Age, y	2.68	<.001*
	BMI, kg/m^2	0.01	.86
	Estimated VO_2peak, mL/kg/min	0.21	.02*
	School 2	0.77	.14
	School 3	2.81	<.001*
	School 4	0.97	.13
	School 5	1.08	.09

Abbreviations: CoDA, Compositional Data Analysis; BMI, body mass index; LPA, light physical activity; MVPA, moderate to vigorous physical activity; SED, sedentary times; TGMD-3, test for gross motor development—third edition; VO_2peak, aerobic capacity. Note: Referent for school is school 1.
*Statistical significance ($P < .05$)

Table 5 Change Prediction Matrix for the TGMD-3 Total Score

	% SED	% LPA	% MVPA
%SED	0	0.68	−0.26
%LPA	−0.68	0	−0.94
%MVPA	0.26	0.94	0

Abbreviations: LPA, light physical activity; MVPA, moderate to vigorous physical activity; SED, sedentary times; TGMD-3, test for gross motor development—third edition.

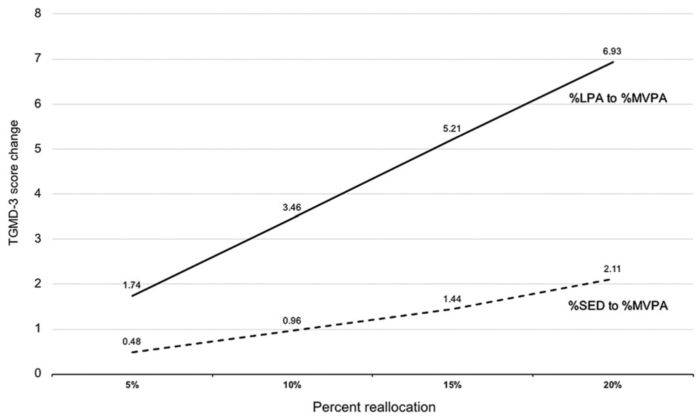

Figure 2 — Adjusted TGMD-3 score changes following percentage reallocation of time between compositional parts. Note: TGMD-3 indicates test for gross motor development—third edition; VO_2peak, aerobic capacity; LPA, light physical activity; MVPA, moderate to vigorous physical activity; SED, sedentary times. Numbers above lines indicate predicted change in TGMD-3 scores; predicted scores adjusted for age, body mass index, and estimated VO_2peak.

relationships are presented as a line graph in Figure 2, showing how a 5% reallocation of composition between parts would associate with TGMD-3 score change.

Discussion

The purpose of this study was to examine the relationship of school day sedentary behaviors and physical activity with gross motor skills in elementary school-aged children using CoDa. Under the CoDa approach and controlling for the covariates of age, BMI, estimated VO_2peak, and school affiliation, a greater proportion of time spent in %MVPA relative to %LPA is associated with higher ball skills and total TGMD-3 scores. A discussion of these findings, implications for practice, and recommendations for future research are provided.

Under the CoDa approach, boys spent less time in %SED and more time in %LPA and %MVPA compared with girls, as evidenced by the relationships communicated in Figure 1. This is congruent with other research in that boys tend to be more active than girls.[27,28] The use of CoDa supports this phenomenon, especially for %MVPA where the greatest contrasts between sexes were observed. Another descriptive characteristic of the sample was the low coefficients within the variation matrix. The observed coefficients are lower (signifying stronger codependence) than those found in other work examining sedentary and physical activity behaviors using CoDa.[16,17,29] This could have been due to the assessment of only school day physical activity, where schedules for most children are structured throughout the day compared with whole-day assessment of physical activity where there could be greater variation in activity. Also, other studies have included sleep behavior within the analysis, which sums the component parts to 4 instead of the 3 assessed in the current study.[17,19] The assessment of more compositional parts may attenuate codependence in certain contexts.

A salient finding from the current study was that a greater proportion of time spent in %MVPA relative to %LPA was associated with higher TGMD-3 scores, which seems to be driven by scores on the ball skills subtest. In some studies, MVPA, when analyzed independently using the traditional approach, has been shown to be significantly correlated with gross motor skills/object control scores in children.[30,31] A 5% reallocation in percentage of time spent in LPA to MVPA was independently associated with a 1.74-point increase in TGMD-3 scores even after controlling for the potential confounders of age, BMI, estimated VO_2peak, and school affiliation. These results align with those found using the traditional approach, but specify that substituting %LPA with %MVPA during school hours associates with higher ball skills. The reallocation of %SED to %MVPA was less pronounced. This may be because the school day already has a set proportion of time spent in %SED because of academic classes. Indeed, it has been shown that school day sedentary behavior can account for as much as 70% of school time.[32] Therefore, it may be difficult to reallocate time from %SED because sedentary behaviors, predominantly sitting, are inherent in the academic classroom, and most schools have bell schedules that are rigidly structured throughout the day.[33] When there is free time for children to be physically active, replacing the %LPA behaviors (eg, standing, slow walking) with more intense movements within a structured or unstructured framework may correlate with better ball skills. Therefore, during school hours, the focus for researchers and practitioners may be to replace %LPA by reallocating more time to %MVPA when attempting to improve ball skills.

Despite the significant relationships observed for the ball skills subtest and total TGMD-3 scores, no statistically significant relationships were observed for the locomotor subtest. This finding is congruent with other work suggesting that the main driver of variation in gross motor skills with physical activity or fitness tends to be variation in the object control/ball skills component rather than variation in locomotor skills.[29,34] Locomotor skill proficiency may develop earlier than object control/ball skills, and many children by the time they reach primary school age are proficient in these skills[35]; therefore, there tends to be a lack of variability in this construct when analyzed in elementary school-aged children. Barnett et al[12] states that object control skills, especially in older children and adolescents, may promote continued participation in a wider variety of physical activities that demand the skills for performance. The results from this study support this hypothesis under the CoDa approach; however, future research needs to explore the relationship between locomotor skills and physical activity in younger children, where the prevalence of locomotor skill proficiency may be lower.

Promoting gross motor skills, specifically ball skills, in school settings is a challenge. However, replacing %SED and %LPA with %MVPA to improve gross motor skills can be accomplished through validated school-based programming.[36] Comprehensive School Physical Activity Programming provides school-based programming that aligns with the Social–Ecological Model and aims to facilitate children meeting the 60 minutes of MVPA guideline.[35] The cornerstone of Comprehensive School Physical Activity Programming is physical education, and it is through quality physical education where students can develop ball skills needed for sustained physical activity participation throughout the lifetime.[35] Reduced activity wait times, providing activity choice, and providing student-centered and developmentally appropriate activity can enhance physical education to improve gross motor skills in children.[35] Other school-based activity promoting methods, such as providing semistructured recesses and providing physical activity within academic classrooms, can be areas where children can replace %SED and %LPA with %MVPA to improve motor competency.[35] It is important that school personnel including administrators, teachers, and staff support programs like

Comprehensive School Physical Activity Programming knowing that the school setting may be one of the few opportunities to implement quality physical activity programming to enhance health in lower income children.

The results of this study manifest potential avenues for future research. As stated previously, conceptual frameworks have been derived relating the constructs of physical activity, health-related fitness, specific motivational constructs, such as perceived competence, and various health-related outcomes. There may be scientific merit in relating these constructs using appropriate mediation, moderated mediation, and path analysis statistical testing under the CoDa approach. For example, one could examine Stodden's conceptual framework using CoDa for physical activity antecedents. In addition, some interventions targeting gross motor skill development use physical activity as an outcome variable.[37] However, instead of analyzing change in physical activity intensities (ie, compositional parts) independently, analyzing change in physical activity under CoDa may provide more relevant information due to the time-constrained nature of assessment. Finally, the CoDa approach may not only have to apply to time-use physical activity data but can also be used to analyze compositional parts of gross motor skill assessment. Locomotor skills and ball skills can be conceptualized as compositional parts that sum to a whole (ie, total TGMD-3 scores). Other instruments that assess gross motor skills use additional compositional parts that comprise a summed comprehensive product- or process-orientated assessment. Analyzing relationships with or change in gross motor skills scores, where the motor skill scores are analyzed under CoDa, may yield new and relevant information (eg, change in locomotor skills relative to change in ball skills).

There are limitations to this study that must be considered before the results can be generalized. First, the sample consisted of low-income elementary school-aged children recruited from the Mountain West region of the United States; therefore, the results of the study may not be generalizable to other age ranges, socioeconomic status groups, and/or geographical locations. Second, the study design was cross-sectional; therefore, no causal inferences can be made. Third, the use of different accelerometer count cut points to classify physical activity intensity (ie, compositional parts) may significantly alter the results, in addition to the use of different accelerometer epoch lengths and sampling rates. Fourth, only school day physical activity was assessed; the results may have differed if physical activity was assessed across an entire day. Finally, although salient potential confounders were controlled for in the general linear models, other potential confounding not observed and accounted for such as stage of physical development and motivational constructs (eg, perceived motor competence, enjoyment) may have affected the observed relationships.

Conclusions

Under the CoDa approach and controlling for pertinent covariates, a greater proportion of time spent in school day %MVPA relative to %LPA associates with higher ball skills and total TGMD-3 scores in a sample of children from low-income schools. There was no relationship between sedentary behavior and physical activity with locomotor skills in children using CoDa, possibly due to the age of the sample and the influence of other confounding. This is the first study examining the relationships between school day sedentary behaviors and physical activity with gross motor skills using the CoDa approach. Results from this study can be used to better inform researchers and practitioners devising interventions targeting physical activity and gross motor skill development, particularly ball skills, in school-aged children.

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