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Association between engagement in physical activity and adaptive behavior in young children with Autism Spectrum Disorder

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ABSTRACT

This study explored whether frequency of engagement in physical activity (PA) was associated with differences in adaptive behavior (i.e., communication, socialization, daily living, and motor skills) among young children recent diagnoses of Autism Spectrum Disorder (ASD). A total of 118 children (32 ± 4 months; 72% boys) underwent physician specialist's evaluation at a university-based neurodevelopmental clinic, alongside their parent (35 ± 7 years; 81% mothers). Children were assessed using the Autism Diagnostic Observation Schedule, Mullen Scales of Early Learning, Vineland Adaptive Behavior Scales, and a physician examination. Parents completed the Weekly Physical Activity Checklist for their child, as well as a self-report depression and demographic questionnaire. After controlling for known confounders, there was a small positive association between frequency of engagement in PA and adaptive behavior (Cohen's $d = 0.36$, 95%CL = ±0.32) ($p = 0.027$). There was also a small positive association between PA and three of the four subdomains of adaptive behavior: socialization ($d = 0.32$, 95%CL ±0.27) ($p = 0.018$), daily living ($d = 0.29$, 95%CL ±0.25) ($p = 0.026$), and motor skills ($d = 0.31$, 95%CL ±0.29) ($p = 0.038$). Frequency of engagement in PA was not statistically significantly associated with children's communication skills ($d = 0.09$, 95%CL ±0.29) ($p = 0.547$). Children with ASD often exhibit delays in adaptive functioning. The associations between PA and adaptive skills observed in our study signals the potential contribution of increased PA as part of early intervention for children with such neurodevelopmental disorders to achieve greater functional outcomes.

1. Introduction

It has been estimated that ~15% of children are affected by neurodevelopmental disorders and/or delays in the first years of life (Boyle et al., 2011). When parents and children manage to obtain access to early intervention services, assessment of adaptive functioning is widely practiced as a core component of such pediatric care (Zwaigenbaum et al., 2015). Adaptive behaviors represent those critical skills that signal one's ability to cope in real life situations, and which children are expected to achieve at key developmental milestones (Tassé et al., 2012). Research shows that children with developmental delays exhibit clear deficits in these adaptive skills, and that this is particularly the case for children with Autism Spectrum Disorder (ASD) (Kanne et al., 2011). Deficits in adaptive functioning among children with ASD can be detected very early in childhood – as early as age two (Ray-Subramanian, Huai, & Ellis Weismer, 2011) – and longitudinal studies show that children with ASD make fewer age-related gains in adaptive functioning when compared with typically developing peers (Sacrey et al., 2019).

Areas most commonly screened using adaptive behavior assessment tools – such as the Vineland Adaptive Behavior Scales (Sparrow, Cicchetti, & Balla, 2005) – include communication, daily living, socialization, and motor skills. If developmental delays in these key areas are not identified and targeted within very early childhood, a key window of

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opportunity for intervention can be missed. For example, research shows that intensive behavioral intervention can be effective for promoting and improving adaptive skills among children with ASD (Dawson & Burner, 2011); and that this is particularly the case during early childhood, at which point children with ASD are less likely to have established patterns of maladaptive behavior (Schreibman et al., 2015). Without such targeted early intervention, however, impairments in adaptive behavior and skills persist throughout childhood and into adulthood (Howlin & Magiati, 2017). Such impairment negatively affects functional independence and, consequently, one's socioeconomic prospects, quality of interpersonal relationships, physical and mental health, and overall quality of life (Howlin & Magiati, 2017). Economic impact assessments also reveal a wider burden, including long-term costs associated with special education needs and medical treatment, and a substantial cost to families as a consequence of lost productivity (Leigh & Du, 2015).

In addition to accessing clinical services for their children, research shows that a large proportion of parents of children with ASD seek complementary therapies (Höfer, Hoffmann, & Bachmann, 2017). One such therapy noted for its efficacy and cost-effectiveness is regular physical activity (PA), which international consensus statements now advocate for as universally beneficial for all children regardless of ability status (Murphy & Carbone, 2008; Rimmer & Rowland, 2008; Rimmer & Vanderbom, 2016). Research shows that engagement in regular PA is associated with benefits in multiple domains of child development (Pate et al., 2019). For example, possible benefits of PA in the context of brain development have been observed (Meijer et al., 2020; Valkenborghs et al., 2019), which is especially relevant for developmental disorders and delays that affect cognitive functioning. Recent systematic reviews of PA in this population group (Bremer, Crozier, & Lloyd, 2016) also provide evidence of its beneficial effects for reducing repetitive and stereotyped behaviors and for improving behavioral regulation, which are particularly common issues among children with ASD.

Despite a noticeable increase in recent years in the number of studies focusing on the prevalence and benefits of PA in the context of developmental disabilities and delays, there remain comparatively few studies on the association between PA and levels of adaptive functioning among children with ASD (Bremer et al., 2016; Sorensen & Zarrett, 2014; cf. Bremer & Cairney, 2020). Therefore, in this study, we explore the association between PA and adaptive behaviors among a clinical sample of young children with a recent diagnosis of ASD. More specifically, after controlling for the confounding influence of known predictors of adaptive functioning in young children exhibiting developmental delays – most notably, child-level cognitive functioning (Zachor & Ben-Itzchak, 2017), parent-level depressive symptomatology (Mazefsky, Williams, & Minshew, 2008; cf.; Golya & McIntyre, 2018), and socioeconomic factors such as household income (Del Cole, Caetano, Ribeiro, & Jackowski, 2017; Kilincaslan et al., 2019) – we hypothesize that differences in children's frequencies of engagement in PA will be associated with differences in their overall levels of adaptive behavior, including differences in communication, socialization, daily living, and motor skills.

2. Methods

2.1. Participants

Participants are a subsample of a larger cohort of children who participated in a study designed to evaluate diagnostic measures of ASD in early childhood, alongside their parent or legal guardian. Children were recruited prior to their initial diagnostic evaluation at a [insert university name here] neurodevelopmental clinic, following parent/guardian request for an evaluation. The clinic's list of requests for an evaluation was screened by clinic staff to identify eligible children (i.e., between the ages of 24 and 39 months), the parents of whom were then contacted by phone and recruited before their first clinic visit. Among the 158 eligible children whose parents were contacted to offer participation in the study, 147 (93%) enrolled. Data collection for this evaluation study of diagnostic measures took place over the course of a year, during which time children and parents attended three clinic visits.

During the first two visits, parents completed all demographic and self-report questionnaires, and clinical researchers administered psychometric evaluations, including either Module 1 or 2 of the Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 2000). During the third visit, a physician evaluated the child and made a clinical diagnosis. A total of 118 children met the criteria for 'autism' and 'autism spectrum' on the ADOS and were diagnosed with Autism Spectrum Disorder (ASD). Data from these 118 children were taken forward in this specific study to address the research question being posed about the association between PA and adaptive behavior in the context of ASD. This study was approved by the [insert university name here] Institutional Review Board. Primary caregivers provided written informed consent to participate in the study.

2.2. Measures

2.2.1. Adaptive behavior

The second edition of the Vineland Adaptive Behavior Scales (Vineland-II) (Sparrow et al., 2005) was used to evaluate children's overall level of adaptive behavior, as well as adaptive skills in four separate domains: communication, socialization, daily living, and motor skills. Research shows that the Vineland-II has excellent validity for use in children with ASD (Sparrow et al., 2005), as well as very high levels of internal (i.e., split-half) and external (i.e., test-retest and inter-rater) reliability (0.86–0.97) (Sparrow et al., 2005). The Vineland-II protocol is administered as a semi-structured primary caregiver interview, during which time the child's performance of a given developmental task or behavior is rated on a Likert-type scale with scores of 0 ("never"), 1 ("sometimes"), and 2 ("usually"). For the present assessment, the full measure was administered, and outcomes were summarized by standard scores (i.e., mean = 100 and SD = 15) based on United States norms. Standard scores for the overall adaptive behavior composite as well as for the four separate domains were used in this study as primary dependent variables.

2.2.2. Physical activity

Parents reported on their child's frequency of engagement in physical activity (PA) using the Weekly Activity Checklist (Sallis et al., 1993). Parents were instructed to report the number of times their child engaged in meaningful bouts of PA during the past week. A list of 28 common activities (e.g., outdoor playing, running, bicycling, sports) was used to prompt parents' responses, and a meaningful bout was defined as activity engaged in continuously for a period of more than 15 min. Parent responses were coded on a weekday-by-activity matrix to derive a total score for child's frequency of engagement in PA. The Weekly Activity Checklist has been shown to have acceptable concurrent validity with other objective measures of PA (Sallis et al., 1993). It has also been shown to have acceptable levels of external (i.e., test-retest) reliability (Sallis et al., 1993). For this study, the child's total number of bouts of PA per week was used as the primary independent variable. A regression equation was also derived from data reported in Sallis et al. (1993) to estimate objectively measured daily PA levels (with its associated prediction interval, or limits, PLs) for our sample. These estimated data were not used directly in the analysis (owing to the fact that they had multiple sources of error, i.e., the original measurement and then subsequent prediction error). However, these data did enable us to better understand the degree to which our sample (on average) was meeting the current PA guidelines of 180 min (of different types of PA at any intensity) spread throughout the day (World Health Organization, 2019). (See the attachment entitled Supplemental Digital Content 1 for a full description of how these estimates of objectively measured PA were derived).

2.2.3. Additional covariates

Given recognition that an 'ecology' of factors can affect both adaptive functioning (Luckasson & Schalock, 2013) and PA, a number of additional socioeconomic, household-, parent- and child-level covariates were assessed as potential confounders. Parents completed a demographic questionnaire, from which data was obtained about their sex, age, ethnicity, number of children, marital status, and annual household income. Research has shown that maternal depression is a risk factor for lower PA among toddlers and preschool children (Bingham et al., 2016). Therefore, parents' depressive symptoms were assessed using the Patient Health Questionnaire (PHQ-9), which is a validated screen for depressive symptoms that has also been used in studies of parents of children with ASD (Kroenke, Spitzer, & Williams, 2001). Parents also reported on the child's general sleep quality by completing the Children's Sleep Habits Questionnaire (Owens, Spirito, McGuinn, & Nobile, 2000). The questionnaire assesses overall sleep disturbance, and scores from the measure have been shown to have acceptable levels of internal (Cronbach's alpha) and external (i.e., test-retest) reliability (Owens et al., 2000). Since its original publication, independent studies have shown the measure to be clinically useful for screening sleep disturbance among toddlers and preschool children with neurodevelopmental disorders, including ASD (Goodlin-Jones, Sitnick, Tang, Liu, & Anders, 2008). Child-level cognitive functioning was assessed using the Mullen Scales of Early Learning (Mullen, 1995), which is a battery of tests designed to measure development in infants and preschoolers. The assessment has excellent (>0.90) internal (i.e., split-half) and external (i.e., inter-rater) reliability (Mullen, 1995), and it has been widely used in Autism research (Lord et al., 2000). In this study, four of the scales were administered and used to generate the Early Learning Composite score, which is widely regarded as a valid measure of early cognitive function (Lord et al., 2000). Finally, children's Body Mass Index (BMI) was calculated using the formula for height and weight, which were measured during the final physician visit. BMI status was categorized according to the Centers for Disease Control and Prevention's percentile calculator.

2.3. Statistical analysis

Data were analyzed in the Statistical Analysis System (SAS) (SAS Studio, University Edition – SAS Institute Inc., Cary, NC, USA). Multivariable analysis (i.e., analysis with a single dependent variable) of the association between children's frequencies of engagement in PA and their overall level of adaptive behavior (i.e., adaptive behavior composite) was conducted using standard multiple regression. Multivariable analysis (i.e., multiple dependent variables) of the associations between frequency of engagement in PA and each of the four subdomains of adaptive behavior (i.e., communication, socialization, daily living, and motor skills) was conducted using a linear mixed model. Multivariable analysis avoided the need for separate models to assess the association between PA and each of the four separate domains of adaptive behavior, an approach that is prone to inflation of Type I error. Using a mixed model also allowed for children to have individual slopes representing the association between PA and each of the four domains. Inclusion of such a random effect is of particular value in the context of the present population, since research shows that, despite core symptoms, children with ASD vary widely in terms of behavioral presentation and differential susceptibility to environmental influences (Geshwind, 2009; Masi, DeMayo, Glozier, & Guastella, 2017).

Both the standard regression and mixed linear models controlled for the confounding influence of covariates by holding them constant at their mean values. The main research question was answered by estimating differences in the dependent variables that were associated with a two standard deviation (SD) difference in PA – i.e., differences in adaptive behavior comparing children with below (mean –1SD) and above (mean +1SD) average frequencies of engagement in PA. The magnitudes of these associations were calculated via standardization and thereafter evaluated according to Cohen's (*d*) scale: $d < 0.2$, trivial; 0.2 to 0.5, small; 0.5 to 0.8, medium; > 0.8, large (Cohen, 1988). Associations are presented alongside their respective *p* values and uncertainties are interpreted as 95%CLs.

2.4. Selection of covariates

Preliminary analyses were conducted according to recommendations for purposeful selection of covariates in a linear model (Bursac, Gauss, Williams, & Hosmer, 2008; Zhang, 2016). A four-step process was used. The first step involved univariable analysis of the predictive value of each individual covariate against a significance threshold of $p \leq 0.25$. Step two involved multivariable analysis of the covariates that met this initial inclusion threshold. Covariates were retained if they fulfilled either of the following criteria: (i) the covariate had a substantial effect size and met a more stringent significance threshold of $p < 0.10$; or (ii) removal of the covariate resulted in a substantial change in the effect size of another (retained) covariate's parameter estimate (i.e., a change of >20%). In step three, linearity of the associations between the retained variables and the dependent variable was assessed. And, finally, in step four, retained covariates were screened for the presence of significant interactional influences. Following this step-by-step process led to the inclusion of three additional covariates in the final model estimating the association between frequency of engagement in PA and adaptive behavior. These were: the child's level of cognitive functioning, parent-reported depressive symptoms, and annual household income adjusted for family size.

3. Results

3.1. Sample characteristics

Descriptive data summarizing the characteristics of the 118 parents and children are displayed in Tables 1 and 2. Socioeconomic- and parent-level data are displayed in Table 1. The sample were mostly of Caucasian ethnicity, with annual household income levels slightly towards the upper end of the distribution (i.e., indicating greater affluence). Approximately three-quarters of parents (35 ± 7 years; 81% mothers) were married, had multiple children, and, on average, reported relatively few depressive symptoms (though data on depressive symptoms were clearly overdispersed). Child-level data are displayed in Table 2. Approximately three-quarters of the sample (32 ± 4 months at the time of their first visit) were boys. The majority were either a healthy weight or slightly underweight, with approximately one-fifth classified as overweight or obese. Parental reports of children's sleep quality were

Table 1
Socioeconomic- and parent-level characteristics of the sample.

Characteristic	Value
Socioeconomic factors	
Ethnicity, No. (%)	
White	85 (72)
Latinx	30 (25)
Missing	3 (3)
Household income, No. (%)	
<$50,000	36 (31)
$50,000 – $100,000	41 (35)
>$100,000	31 (26)
Missing	10 (8)
Parent-level factors	
Mothers, No. (%)	95 (81)
Age, mean (SD) [No. missing]	35.24 (7.25) [12]
Married, No. (%)	84 (71)
Missing	3 (3)
Number of children	2.25 (1.26) [3]
Number of self-reported depressive symptoms	4.20 (4.70) [10]

Abbreviations; No., number; SD, standard deviation.

Table 2
Child-level characteristics of the sample.

Characteristic	Value
Boy, No. (%)	87 (74)
Missing	3 (3)
Age in months, mean (SD) [No. missing]	31.87 (4.35) [3]
BMI percentile, No. (%)	
Underweight: <5th percentile	10 (8)
Healthy weight: 5th – 85th percentile	75 (64)
Overweight: 85th – 95th percentile	13 (11)
Obese: > 95th percentile	13 (11)
Missing	7 (6)
Sleep quality[a], mean (SD) [No. missing]	46.40 (8.32) [22]
Cognitive functioning[b], mean (SD) [No. missing]	63.79 (16.29) [6]
Adaptive behaviors composite score[b], mean (SD) [No. missing]	79.77 (12.51) [3]
Communication skills[b], mean (SD) [No. missing]	75.58 (14.55) [3]
Socialization skills[b], mean (SD) [No. missing]	80.97 (14.35) [3]
Daily living skills[b], mean (SD) [No. missing]	82.93 (13.33) [3]
Motor skills[b], mean (SD) [No. missing]	89.46 (13.83) [3]
Total number of PA bouts per week, mean (SD) [No. missing]	17.39 (12.13) [3]
Estimated daily PA in minutes, mean (95%PL[c]) [No. missing]	108.29 (64.73) [5]

Abbreviations: No., number; SD, standard deviation; BMI, body mass index; PA, physical activity; PL, prediction limits.
[a] T score (mean = 50, SD = 10).
[b] Standard score (mean = 100, SD = 15).
[c] The prediction limits represent the lower (108.29–64.73) and upper (108.29 + 64.73) bounds within which the estimated daily PA in minutes value will lie in 95% of random samples.

approximately average (i.e., sample T score of ~50). However, results from the Mullen Scales of Early Learning indicate that the mean score fell on the 2nd percentile of the normal distribution, indicating impaired cognitive functioning. As for the key outcome variables of interest, children were also on the lower end (<25th percentile) of the distribution for adaptive behavior, including borderline impairment of communication (7th percentile), and below-average socialization (13th percentile), daily living (14th percentile), and motor skills (23rd percentile). Finally, whilst parents reported that their children were engaging in multiple bouts of PA across the week, estimated levels of objectively measured daily PA (108.15 ± 8.14, 38.93; estimated daily PA in minutes ± standard deviation, range) indicates that the sample was falling well short of the recommended guidelines of 180 min spread throughout the entire day.

3.2. Primary analysis

Standard linear regression assumptions were used to evaluate the appropriateness of the model to fit the observed data. Two items are particularly noteworthy. First, two outliers were removed after their standardized residuals were observed to exceed a critical value (i.e., the residual value for a datapoint divided by its estimated standard error > 3). And second, to ensure that the residual error variances from the regression model were normally distributed, the logarithmic transformation was applied to the cognitive functioning and parent-reported depressive symptoms variables. Once these changes were made to the observed data, the Q-Q, fitted versus residuals, and scale location plots confirmed that the final regression model satisfied the assumptions of normality, linearity and homoscedasticity, respectively. These plots are attached and explained in Supplemental Digital Content 2.

The final regression model was statistically significant, $F_{(4,\ 112)} = 18.11$, $p < 0.001$, and represented a good fit to the data. Table 3 displays the resulting unstandardized and standardized regression coefficients, Cohen's d effect sizes with 95% confidence intervals, squared semi-partial correlations, R^2, and adjusted R^2. An adjusted R^2 value of 0.37 indicates that over a third of the variability in child-level adaptive behavior was explained by the four predictors in the model, and the semi-partial correlations (sr^2) displayed in Table 3 confirm the substantial confounding influence of individual covariates. The

Table 3
Multiple regression model estimating the association between frequency of engagement in PA and adaptive behavior, including confounding influence of additional covariates.

	B	β	d, ± 95% CL[a]	sr^2	p value
Engagement in PA	4.31	0.18	0.36, ±0.32	0.03	0.027
Cognitive functioning	25.02	1.05	2.09, ±0.69	0.21	<0.001
Household income	6.96	0.29	0.58, ±0.32	0.08	<0.001
Parental depressive symptoms	−3.69	−0.29	−0.58, ±0.32	0.07	0.025
			$R^2 = 0.39$, Adjusted $R^2 = 0.37$		

Notes: B = unstandardized beta coefficient; β = standardized beta coefficient; d = Cohen's d. Cohen's d for engagement in PA and household income represents the difference in adaptive behavior associated with a 2SD change in the predictor (divided by the between-subjects SD for adaptive behavior); with logarithmic transformation of the predictors, Cohen's d for cognitive functioning and parental depressive symptoms represents the difference in adaptive behavior associated with a 10% difference in the predictor (divided by the between-subjects SD for adaptive behavior); sr2 = squared semi-partial correlation coefficient.
Abbreviations: PA, physical activity; CL, confidence limits; SD, standard deviation.

contribution of cognitive functioning is particularly noteworthy – its removal from the regression resulted in an 21% reduction in predictive value. Taken together, parent-reported depressive symptoms and annual household income contributed an approximate 15% of predictive value. Also noteworthy is the minimal joint contribution of the predictors – subtracting the sum of the squared semi-partial correlations from the overall R^2 value revealed a level of shared variability of <1%. This is a testament to the independent value of each of the predictors screened for inclusion in the final model.

As for our primary research question, after controlling for the confounding influence of cognitive functioning, parent-reported depressive symptoms, and annual household income, frequency of engagement in PA had a statistically significant positive association with child-level adaptive behavior. As for the magnitude of the association, a two standard deviation difference in children's frequencies of engagement in PA was associated with a small, but substantial, increase in adaptive behavior (Cohen's $d = 0.36$, 95%CL = ±0.32) ($p = 0.027$).

3.3. Adaptive behavior subdomain analysis

Further analysis was conducted to estimate the extent of (and possible difference in) the associations between frequency of engagement in PA and each of the four subdomains of adaptive behavior. A separate multivariable mixed model was specified which allowed for: (i) multiple dependent variables with different measurement error terms; (ii) multiple slopes to represent potential differences in the association between engagement in PA and each of the four subdomains of adaptive behavior; and (iii) a random effect to allow for potential differences in the association between PA and each subdomain between individual children.

After controlling for the influence of confounders, unequal variances among different dependent variables, as well as possible differences in the outcomes between individual children, the subdomain analysis revealed that frequency of engagement in PA had a small statistically significant positive association with children's levels of socialization ($d = 0.32$, 95%CL ±0.27) ($p = 0.018$), daily living ($d = 0.29$, 95%CL ±0.25) ($p = 0.026$), and motor skills ($d = 0.31$, 95%CL ±0.29) ($p = 0.038$). Frequency of engagement in PA was not statistically significantly associated with children's communication skills ($d = 0.09$, 95%

CL ±0.33) ($p = 0.547$) (see Table 4).

4. Discussion

This study explored the association between frequency of engagement in PA and level of adaptive behavior among a clinical sample of young children with recent diagnoses of Autism Spectrum Disorder (ASD). Results showed a positive association, with frequency of engagement in PA explaining a substantial unique proportion ($sr^2 = 0.03$, or 3%) of the variability in adaptive behavior after controlling for the influence of known confounders. Subsequent subdomain analysis revealed that frequency of engagement in PA had a positive association with three of the four domains of adaptive behavior – socialization, daily living and motor skills – but not with communication skills.

Taken together, these findings suggest that, while bouts of PA in early childhood may help a child develop social, motor, and other daily living skills, the impact of this type of PA may not directly benefit language or communication skills. These findings are mostly likely explained by the very young age of the sample, combined with evidence of impairment to cognitive function and, as yet, limited exposure to early intensive behavioral intervention. Whilst it is highly likely that the development of language and communication skills in this population group at this young age requires direct therapeutic approaches – e.g., speech therapy – recent studies do signal the possibility that the outcomes of such therapeutic interventions could be further maximized by inclusion of a PA- or play-based component (Stamou, Roussy, Ockelford, & Terzi, 2019; cf.; Hassani, Sheikh, & Shahrbanian, 2020; Hassani, Shahrbanian, Shahidi, & Sheikh, 2020).

The results of this study clearly complement and extend recent research on associations between active lifestyles and positive outcomes for children with developmental delays by Neville, Guo, Boreham, and Lakes (2021), which (in a slightly older and much larger cohort) showed that weekly engagement in organized sports was associated with a significant relative reduction in behavioral difficulties among boys exhibiting developmental delays between the ages of 3 and 5 years. The present study is additionally novel, however, in that it is among the first to show a positive association between PA and adaptive behavior in a clinical sample of children with recent diagnoses of ASD. Despite very limited research on PA and adaptive behavior in the context of ASD, a recent study (Bremer & Cairney, 2020) in an older cohort (ages 7–12 years old) provides evidence which indicates that adaptive behavior could moderate the relationship between motor competence and health-related fitness. Combined with the results of this study, these results suggest the possibility of a virtuous cycle, whereby early childhood PA could promote adaptive functioning, which, in turn, could provide the building blocks for developing more complex and specialized skills – such as those required to play games, compete in sports, and participate in recreational activities more generally.

Practically speaking, the evidence provided in this paper is important because it could positively affect attitudes towards, and beliefs about, PA for very young, developmentally vulnerable children – particularly the attitudes and beliefs of parents. In a recent study of infants and toddlers with developmental delays, for example, Lakes et al. (2019; Lakes et al., 2017) found that parents viewed PA as less beneficial and more difficult to access for their child, which in turn predicted less time spent by their child in weekly PA, as well as a lack of perceived ability among parents to influence their child's PA. In another report from the same cohort, Lakes, Neville, Abdullah, and Donnelly (2020) found that parental perceptions about the benefits of PA for their child was a strong predictor of weight status in children with developmental delays: the proportion of children classified as overweight or obese was approximately 4 times larger for parents with below average perceptions about the benefits of PA. It is little wonder that research consistently shows children with developmental disabilities accessing less PA (Case, Ross, & Yun, 2020) and having an increased risk of obesity than their typically developing peers (Kahathuduwa et al., 2019; Zheng et al., 2017).

Since children with developmental disabilities such as ASD face substantial barriers to PA (McGarty & Melville, 2018; Shields & Synnot, 2016; Shields, Synnot, & Barr, 2012), strong empirical evidence of PA's direct and condition-specific benefits is needed to support parent motivation and determination to pursue opportunities for PA in the face of many individual, social, and environmental barriers (Lakes et al., 2019). Evidence that PA is positively associated with adaptive functioning in children with ASD can inform pediatricians on the front line of practice working with families to develop comprehensive early intervention strategies in this population group (Zwaigenbaum et al., 2015). Patient education provided by pediatricians can directly influence parent behavior and family activity planning. It can also indirectly influence planning among daycare providers, schools, and regional assessment centers. When combined, these factors can result in more opportunities for PA and perhaps even improved body composition and adaptive skills for this population of developmentally vulnerable young children.

Brief consideration of the confounding influence of covariates reported in this study is also warranted. The findings of this study build upon some of what has already been shown in previous studies of families and young children with ASD. For example, in a study of factors associated with response to intervention in ASD, Ben-Itzchak and Zachor (2011) reported that 40% of the variability in adaptive behavior change over time was predicted by baseline levels of cognitive functioning. As for the association between parent-reported depressive symptoms and child-level adaptive behavior, data reported in this study builds upon recent research by Golya and McIntyre (2018). In a sample of children aged 21–83 months, Golya and McIntyre (2018) found possible associations between parental self-reported depression and socialization (−0.16, ±0.25; correlation coefficient, ±95%CL) and daily living skills (−0.19, ±0.25; correlation coefficient, ±95%CL). However, their study was not adequately powered (n = 60) to detect such small, but possibly substantial, correlations. Data on the association between annual household income and levels of adaptive behavior among children with ASD remains sparse. Research mostly reports socioeconomic disparities in the rates of diagnosis of ASD as well as access to support services among low-income families (Eilenberg, Paff, Harrison, & Long, 2019). The data reported in this study is therefore novel in that it signals a possible contribution of socioeconomic deprivation to inhibited adaptive functioning among very young children diagnosed with ASD.

Table 4
Association between frequency of engagement in PA and each of the four subdomains of adaptive behavior, adjusting for confounding influence of additional covariates.

	d, ± 95%CL[a]	*p* value
Communication Skills	0.09, ±0.29	0.547
Socialization Skills	0.32, ±0.27	0.018
Daily Living Skills	0.29, ±0.25	0.035
Motor Skills	0.31, ±0.29	0.038

Note: d = Cohen's d. Cohen's d represents the differences in each of the four subdomains of adaptive behavior associated with a 2SD difference in PA (divided by the between-subjects SD for adaptive behavior).
Abbreviations: PA, physical activity; CL, confidence limits; SD, standard deviation.

4.1. Limitations and future research directions

Despite the strengths of this study, several limitations should be acknowledged and can inform future research. Measurement of PA represents a possible limitation, since parental reports of PA are known to have some recall bias and since the measure used was initially validated in older children (Sallis et al., 1993). The line of research pursued in this study would benefit from immediate replication using objective measures of PA. Sensitivity to activity bout duration and intensity is particularly important for future research in this population –

particularly, aspects of PA that could overlap with repetitive behaviors and/or restricted interests – with a recent study by Schmitz et al. (2017) observing that longer duration and higher intensity activities exacerbated maladaptive behaviors in children with ASD. In slightly older cohorts, sensitivity to activity type could also be important, with recent studies also noting differences in the efficacy of PA interventions across different types of activity – more specifically, whether the PA was predominantly aerobic, physical education or motor skill-based, or cognitively engaging (Vazou, Pesce, Lakes, & Smiley-Oyen, 2019; see also Pesce et al., 2019; Tomporowski & Pesce, 2019). Given that children with ASD can vary widely in terms of their response to treatment (Golya & McIntyre, 2018; Ben-Itzchak & Zachor, 2011; Zachor & Ben-Itzchak, 2017) research exploring the association between PA and adaptive behavior across different types of PA is a worthwhile avenue for future research in this population group.

Despite use in this study of a systematic approach to select meaningful covariates – many of which are known to affect outcomes of early interventions in the context of ASD (Ben-Itzchak & Zachor, 2011) – the study was still somewhat limited in its ability to explore differences in the association between PA and adaptive behavior among different groups. For example, the sample in this study was ~75% male, so meaningful analysis of sex differences in the associations between PA and adaptive behavior was not possible. Such an analysis should be prioritized in future research. Moreover, although screening for the confounding influence of ethnicity was undertaken, this study was also somewhat limited in its ability to examine further racial and ethnic disparities in PA and adaptive behavior. This is primarily due to the demographics of the region within which the study was undertaken, where families are predominantly Caucasian or of Latinx descent. Replication of this study in other population groups who experience known health disparities – such as African American/black children where symptom severity is reported as being higher than in Caucasian (Becerra et al., 2014) – should be prioritized in future research.

Finally, the associations observed in this study cannot demonstrate a causal relationship between PA and adaptive behavior in the very early stages of diagnosis. Randomized controlled trial studies are needed to address this gap in the literature. Longitudinal panel studies are also needed to address what could be a complex bidirectional relationship, wherein engagement in PA promotes the development of adaptive behavior whilst poor adaptive functioning also serves as a barrier to engagement in many forms of PA (particularly structured PA). Whilst there is a growing research literature in this area, more work needs to be done to evaluate the impact of PA interventions on adaptive functioning in early childhood – particularly among young children with recent diagnoses of ASD. Complementary research should also address the interpersonal (e.g., buddy systems) and instructional strategies (e.g., early years pedagogical frameworks) that promote further inclusion of children with ASD in community-, daycare-, and school-based programs designed to promote increased levels of PA. Testing for possible differences in the effectiveness of different physical education instructional strategies is a particularly fruitful avenue for future ASD research. For example, research on PA for children with ASD is often still rooted in an activities-based approach – i.e., this or that activity (such as swimming, martial arts, dance, horse-riding, etc.) is more or less beneficial for this population group (because its biomechanics matches behavioral stereotypy, or because it has pleasant or reinforcing sensory consequences) (see e.g., Bremer et al., 2016; Lang et al., 2010, Tse, Pang, & Lee, 2018). However, instructional strategies that have been successfully used in physical education settings with children with ASD – such as Teaching for Personal and Social Responsibility (Hellison, 2011), Sport Education (Siedentop, Hastie, & Van-der-Mars, 2011), Cooperative Learning (Grenier & Yeaton, 2019), Universal Design (Grenier, Miller, & Black, 2017), and other forms of models-based practice (Casey, 2014; González-Víllora, Evangelio, Sierra-Díaz, & Fernández-Río, 2019) – could be viable and much more generalizable options for researchers seeking to reliably scaffold children's social interaction, learning and engagement during any type of PA intervention.

5. Conclusion

This study is among the first to explore the association between PA and adaptive behavior in a clinical sample of young children with recent diagnoses of ASD. Research already shows that early intervention is critical (Ben-Itzchak & Zachor, 2011), and that combined developmental and behavioral interventions work best to improve adaptive functioning among children with ASD (Zwaigenbaum et al., 2015). The results of this study contribute new evidence to support the inclusion of PA in future recommendations for the practice of early intervention in the context of ASD and other related neurodevelopmental disorders (Zwaigenbaum et al., 2015). Children with such developmental disabilities are already known to be less physically active and more vulnerable to direct exclusion from structured forms of PA, such as leisure-time play and games, and participation in organized sports (Bremer et al., 2016; Lakes et al., 2017, 2019; Murphy & Carbone, 2008; Rimmer & Rowland, 2008; Rimmer & Vanderbom, 2016). Therefore, this study could also be directly beneficial for pediatricians who seek to advise parents on healthy activity planning for their family, and for advocacy agents and groups who seek to ensure equitable access to structured forms of PA and play for developmentally vulnerable children.

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Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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