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ORIGINAL RESEARCH

A Comparison of the Fundamental Motor Skills of Preschool-Aged Children With and Without Visual Impairments

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Fundamental motor skills (FMS) are an underlying mechanism driving physical activity behavior and promoting positive developmental trajectories for health. However, little is known about FMS of preschool-aged children with visual impairments (VI). The purpose of this study was to examine the FMS of preschool-aged children ($N = 25$) with ($n = 10$) and without ($n = 15$) VI as measured using the Test of Gross Motor Development-3. Children without VI performed significantly higher than their peers for locomotor ($M = +11.87$, $p = .014$, $\eta^2 = .31$) and ball skills ($M = +13.69$, $p < .001$, $\eta^2 = .56$). Regardless of the presence of a VI, many participants struggled with developing FMS, with the greatest disparity resting within ball skills. These findings help to clarify the FMS levels of preschool-aged children with VI. Thus, there is a need for both further inquiry and intervention for all children.

Keywords: blindness, disability, early childhood, gross motor skills, motor competence

Fundamental motor skills (FMS), typically classified as locomotor (e.g., run, hop, and jump) and ball skills (e.g., throw, catch, and kick), are also known as the "building blocks" for more advanced movement patterns, physical activity participation, and sports and games (Clark & Metcalfe, 2002; Seefeldt, 1980). The preschool years (e.g., ages 3–7 years) are a critical time for children to learn FMS (Brian, Pennell, Taunton, et al., 2019; Clark & Metcalfe, 2002; Seefeldt, 1980). If children do not learn FMS during the preschool-aged years, resulting in a gross motor skill developmental delay, they may have a more difficult time attempting to learn FMS later (Brian, Pennell, Taunton, et al., 2019; Clark & Metcalfe, 2002;

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Seefeldt, 1980). FMS delays in preschool often result in persistent developmental delays throughout childhood into adolescence (Robinson et al., 2015; Stodden et al., 2008). Developmental delays, which persist into adolescence can result in a negative and recurring spiral of disengagement with health-enhancing behaviors like physical activity (Stodden et al., 2008), leaving individuals with developmental delays more vulnerable to hypokinetic diseases (e.g., Type 2 diabetes, metabolic syndrome, etc.). Unfortunately, as many as 78% of preschool-aged children in the United States experience gross motor developmental delays regardless of age, geographic location, socioeconomic status, and rural versus urban environments (Brian, Taunton, et al., 2019).

Unlike age, socioeconomic status, and location, the presence of a documented disability increases the risk of FMS developmental delay in preschool-aged children (Brian, Taunton, et al., 2019), regardless of disability type (Kim et al., 2016; Taunton et al., 2017). However, children with visual impairments (VI), including those with blindness or low vision, often show extreme developmental delays (<5th percentile) with their FMS (Brian et al., 2018; Haegele et al., 2015; Haibach et al., 2014; Houwen et al., 2007), which are often significantly more profound than those of their peers without disabilities (Wagner et al., 2013). Interestingly, biological sex and age do not tend to affect the FMS of youth with VI; yet, degree of vision almost always plays a role (Brian, Pennell, Haibach-Beach, et al., 2019; Haibach et al., 2014). Often, as vision improves so does FMS (Brian et al., 2018; Brian, Pennell, Haibach-Beach, et al., 2019; Brian, Bostick, et al., 2020; Haibach et al., 2014).

To understand the nuances of how vision affects FMS development, one must first explore the often contested views surrounding the way in which motor skill learning occurs. Motor skill development and learning is age-related not age-dependent (Clark, 2007). From a dynamical system and a constraints theory perspective (Newell, 1984, 1986), motor skill learning is the result of the dynamic and transactional interaction among three constraints (task, environment, and organism). Theoretically, in order to maximize motor skill learning, the organism needs to experience developmentally appropriate tasks (which accommodate for functional and structural constraints) within their given environment. After experiencing developmentally appropriate tasks, the motor control system would then self-organize to create the movement patterns necessary for motor competence. Without positive learning experiences, or opportunities to practice FMS, the individual will not "learn" FMS naturally as a result of time (Brian & Taunton, 2018; Brian et al., 2017; Gagen & Getchell, 2006; Getchell & Gagen, 2006; Goodway & Branta, 2003; Shmuelof et al., 2012). That being said, it is possible that children with VI struggle with learning FMS because they are not experiencing developmentally appropriate task opportunities in a safe and positive environment.

Given that children with VI are greatly at risk for difficulties with FMS, which may have further future health consequences, it is important to better understand how the FMS of preschoolers with VI is developing compared with peers without VI. Furthermore, this is the first examination of the FMS of preschoolers with VI. Thus, these data can shed insight into potential developmental trajectories of youth with VI and provide recommendations for intervention timing, if necessary. Therefore, the purpose of this study was to examine the FMS of preschool-aged children with and without VI. We hypothesized that children with VI would show significantly lower locomotor and ball skills than children with VI.

Methods

Design

This study featured a cross-sectional, descriptive-analytic design with purposive sampling.

Participants

Participants ($N = 25$; boys = 12; girls = 13) included children aged 3–5 years (M_{age} = 4.23 years, $SD = .51$; Latinx = 15; African American = 7; European American = 3) from a preschool center in the southeastern region of the United States. All children who were Latinx spoke English as a second language.

Within the preschool center, administrative staff reported 10 children with a documented VI (B1 = 2, B3 = 4, B4 = 4) based upon the United States Association of Blind Athletes vision classification (see below) and 15 children were not visually impaired. Regarding the children with VI, etiologies included glaucoma, optic nerve hypoplasia, retinal detachment, exotropia, retinopathy of prematurity, aniridia, nystagmus, foveal hypoplasia, esotropia, and myopia. Of the 10 children with a VI, seven were born with a VI and the other three acquired VI later. All children enrolled in the preschool center were considered socioeconomically disadvantaged. No child included in this sample had multiple, documented disabilities beyond VI.

Setting

The preschool center was an urban school in the southeastern United States. The center contained five classrooms and approximately 54 students (28 possessed a VI). The center was a full-day preschool from approximately 7:30 a.m. to 2:30 p.m. with daily recess for 60 min per day for all children (two, 30-min sessions per day). Gross motor space included two outdoor play spaces for recess located on the sixth floor of the building (herein referred to as balconies) and a former classroom converted into a space for physical and occupational therapies. Balcony 1 was a large space in which children could play with playground balls, sidewalk chalk, large play bricks for building, and tricycles. Balcony 2 included two stationary playground structures, gymnastics mats, two small slides, and blocks for building. Classroom teachers supervised all recess sessions but provided no formal FMS instruction or structured activities for children.

VI Classification

The United States Association for Blind Athletes classification scale served as the VI classification system and incorporates four levels (B1, B2, B3, and B4). B1 includes no light perception in either eye up to light perception and an inability to recognize the shape of a hand at any distance or in any direction and is considered the lowest level of visual acuity. Children who are B2 can recognize the shape of a hand with a visual acuity up to 20/600; B3 include 20/600—20/200. Both B2 and B3 may or may not include a visual field of $<5°$ in the best eye including eye correction. In contrast, children who are B4 possess visual acuity above 20/200 and up to visual acuity of 20/70 and a visual field >20° in the best eye with the best practical eye correction. B4 is considered the highest visual acuity.

Instrumentation

The Test of Gross Motor Development-Third Edition (TGMD-3; Ulrich, 2019) features robust psychometric properties for children between the ages of 3 years and 10 years and 11 months. The TGMD-3 includes 13 FMS divided into two separate subscales (locomotor skills and ball skills). The locomotor subscale contains six skills, which include running, galloping, hopping, jumping, skipping, and sliding. The ball skills subscale contains seven skills, which include throwing, kicking, catching, one-hand strike, two-hand strike, tossing, and dribbling. Each locomotor and ball skill feature between 3 and 5 critical elements of individual skill performance. During the scored trials of the skill, a trained coder gives the child a score of 1 if the critical element is present and a 0 if the critical element is not present. A child then receives a raw skill score ranging between 0 and 8 points for each locomotor skill and 0 and 10 points for each ball skill. A sum of each raw skill score in each subscale provides the child's overall subscale score. For locomotor skills, skill scores are out of a total of 46 points and balls skills are out of a total of 54 points. The total assessment raw scores range from 0 to 100. Raw scores can then be converted into percentile ranks for a normative reference using the conversion tables in the manual (Ulrich, 2019).

In 2018, Brian et al. examined psychometric properties of the TGMD-3 for children with VI. The TGMD-3 revealed high internal consistency ($\omega = .89–.95$), strong interrater reliability (intraclass correlation coefficient = .91–.92), convergence with the TGMD-2 ($r = .96$), and good model fit, $\chi^2(63) = 80.10$, $p = .072$, χ^2/df ratio = 1.27, root mean square error of approximation = .06, comparative-fit index = .97. Furthermore, they also examined the content and face validity of modifications TGMD-3 (Brian et al., 2018). For examples of modifications of the TGMD-3 for children with VI, please refer to Brian et al. (2018).

Procedures

We selected the purposive sample at the preschool center based upon available participants who completed all measures. All racial/ethnic, sex, and age breakdowns occurred via convenience. We obtained institutional review board approval from the University of South Carolina. Parents provided written consent and all children provided verbal assent. All testing occurred in September (approximately 1 month after the start of the year) and during the morning before lunch. Assessments occurred in the gross motor spaces provided at the center. We video recorded each of the scored TGMD-3 trials and retroactively coded the sample.

We assessed all children without a VI following the standardized procedures of the TGMD-3 (Ulrich, 2019) and utilized the modifications and procedures for children with VI when appropriate (Brian et al., 2018). We first provided a demonstration of each skill. Participants completed a practice trial. If necessary, we followed the least-to-most prompting structure and modifications recommended by

Brian et al. (2018). Afterwards, children completed two scored trials for each skill. The center provided an interpreter for the 12 children who spoke English as a second language.

Data Analysis

TGMD Coding Procedures

Three trained members of the research team coded the trials from the TGMD-3. We ensured all coders reached interrater reliability at or above 90% as a "gold standard" for coders prior to coding the current sample. After coding, we conducted a secondary interrater reliability across 30% of the coded sample. The raters reached an interrater reliability of 88.2% across the entire 30% of the sample.

Data Analysis

Prior to any formalized analyses, we tested for all statistical assumptions including linearity, multicollinearity, univariate/multivariate outliers, normality, and homogeneity of variance. Next, we conducted descriptive analysis (means/*SD*s) for scores of the TGMD-3 across locations for both ball skills and locomotor subscales (Table 1). Subsequently, for descriptive purposes, we converted all raw scores into percentile ranks using the conversion tables within the TGMD-3 manual (Ulrich, 2019; see Table 1). Next, using raw scores, we conducted a two vision (VI, no VI) multivariate analysis of covariance for locomotor and ball skills after controlling for age and sex. Age and sex were not significant, so they were removed from the model. We followed up with a two (vision) multivariate analysis of variance to explore differences in locomotor and ball skills (RQ1).

Results

Assumptions

The locomotor and ball skills scores were moderately correlated ($r = .67$, $p = .002$) warranting the use of multivariate analysis of variance (Hair et al., 2018). There was a linear relationship as assessed by a scatter plot. There were no univariate outliers as assessed by inspection of a boxplot. There were no multivariate outliers as

Table 1 Descriptive Analysis of TGMD-3 Scores

Participant group ($N = 25$)	LM raw scores, M (SD)	BS raw scores, M (SD)	LM percentile rank	BS percentile rank
Without VI ($n = 15$)	22.47 (6.98)	19.83 (5.95)	50th	37th
With VI ($n = 10$)	10.60 (3.18)	6.14 (6.46)	9th	2nd

Note. VI = visual impairment; LM = locomotor; BS = ball skills; TGMD-3 = Test of Gross Motor Development-Third Edition. Locomotor subscale scores can range from 0 to 46. Ball-skills subscale scores can range from 0 to 54.44.

assessed by Mahalanobis distance ($p > .001$). Both locomotor and ball skills scores were normally distributed as assessed by Shapiro–Wilk's test ($p > .05$). There was homogeneity of covariance matrices as assessed by Box's M test ($p = .404$). There was homogeneity of variances as assessed by Levene's test ($p > .05$).

Locomotor Skills

Children's locomotor skills ranged from 0.00 to 37.00 ($M = 17.72$, $SD = 10.22$) out of a total possible 46 points. Children without VI showed the highest locomotor skills (10.00–37.00; $M = 22.47$, $SD = 6.98$; 50th percentile; Table 1) when compared with children with VI (0.00–28.00; $M = 10.60$, $SD = 10.45$; 9th percentile; Table 1). There were significant main effects for vision ($F = 17.55$, $p = .014$, $\eta^2 = .31$). For children with a VI, those whose onset occurred at birth ($n = 7$) performed higher ($M = 10.43$, $SD = 10.64$) than those whose onset occurred later ($n = 3$; $M = 4.00$, $SD = 2.83$).

Ball Skills

Children's ball skills ranged from 0.00 to 28.00 ($M = 14.79$, $SD = 9.03$) out of a total possible 54 points. Children without VI showed the highest ball skills (8.00–28.00; $M = 19.83$, $SD = 5.95$; 37th percentile; Table 1) when compared with children with VI (0.00–16.00; $M = 6.14$, $SD = 6.46$; 5th percentile; Table 1). There were significant main effects for vision ($F = 21.99$, $p < .001$, $\eta^2 = .56$). For children with a VI, those whose onset occurred at birth ($n = 7$) performed higher ($M = 6.83$, $SD = 6.79$) than those whose onset occurred later ($n = 3$; $M = 2.00$, $SD = 1.02$).

Discussion

The purpose of this study was to examine the locomotor and ball skills of preschool-aged children with and without VI. We hypothesized that children with VI would show significantly lower locomotor and ball skills than children with VI.

Locomotor and Ball Skills of Preschool-Aged Children With and Without VI

All participants, regardless of degree of VI, showed actual developmental delays (e.g., 5th–25th percentiles) or were at risk for developmental delay (e.g., 37th percentile) with their ball skills. For locomotor skills, children without VI (as a group) did not demonstrate a developmental delay (50th percentile) while children with VI did show developmental delays (see Table 1). The prevalence of developmental delays within this sample is not surprising. According to Brian, Pennell, Taunton, et al. (2019) preschool-aged children in the United States may be experiencing a secular decline with their FMS. That is, the FMS of today's children is significantly lower than the FMS of children 20–35 years ago (Brian, Pennell, Taunton, et al., 2019). Furthermore, the presence of a documented disability often increases the risk for developmental delay in preschool-aged children (Brian, Pennell, Haibach-Beach, et al., 2019). Thus, the severe delays presented by the children with VI are consistent with data from other samples that include a variety of disabilities (e.g., Brian, Pennell, Taunton, et al., 2019) and are very alarming.

Why Are Profound Delays With FMS So Alarming? The children in this sample, for the most part, presented with severe developmental delays (e.g., 5th percentile) or are at risk for delays (e.g., greater than the 30th percentile). FMS are critical to overall child development. FMS not only relates to health-enhancing physical activity behaviors for children without VI (e.g., Robinson et al., 2015) and children with VI (e.g., Brian, Pennell, Haibach-Beach, et al., 2019) but other aspects of whole child health. FMS relates to self-perceptions (e.g., Robinson & Goodway, 2009), social–emotional development (e.g., Cummins et al., 2005), executive functioning (e.g., Aadland et al., 2017), school readiness (e.g., Chang & Gu, 2018), and literacy/numeracy (e.g., Macdonald et al., 2018). If children are experiencing FMS delays, it is likely that these delays have a cascading effect across multiple aspects of child development and will continue to compound across developmental time.

Could Preschool Be the Start of the Track Toward Arrested Development? Today's children, including those within this sample, are more likely to demonstrate delays with their FMS than those at any other time in history (Brian, Pennell, Taunton, et al., 2019). Recent data from Brian et al. (2021) infers that adolescents with VI are showing high prevalence of arrested development. Arrested development refers to stoppage in development for domains, such as gross motor, where changes are expected across time (Brian et al., 2021). Clearly, developmental delays are occurring in preschoolers with VI with greater deficits trending for those who acquire VI after birth. Intervention, which is highly effective for children with VI (e.g., Brian et al., 2020) needs to occur immediately at the signs of developmental delay. Perhaps early intervention needs to occur for all children, through the form of physical education, in universally-designed preschool settings. However, further research is needed.

Limitations

Although this study showed new findings for preschool-aged children with VI, this study certainly is not without limitations. VI is a low-incidence disability making it difficult to find multiple children with VI at any given school that is not specially designed to accommodate learning for both children with and without VI in the same classroom. Finally, given the small sample size, we do not suggest that these data represent a broad population of preschoolers with VI. Thus, generalizability may not be possible.

Implications

There are many implications from this study that certainly can be the focus of a future research and inquiries. Unfortunately, the children with VI in this sample showed significant developmental delays warranting the need for intervention. Although the children with VI in this sample received daily recess, physical therapy, and occupational therapy, they did not receive physical education. FMS intervention can very quickly remediate FMS delays in preschool children with and without VI (e.g., Brian et al., 2020). Intervention is most effective when it occurs early. Ball skills and locomotor skills are particularly important for children with VI. For example, in a sample of adolescents with VI, ball skills and locomotor skills emerged as the only significant correlate of moderate to vigorous physical activity participation and mile run time when compared with other measures of health-related fitness, such as muscular strength, muscular endurance, and body mass index (Brian, Pennell, Haibach-Beach, et al., 2019). In fact, locomotor and ball skills were a more powerful factor with physical activity than degree of vision (Brian, Pennell, Haibach-Beach, et al., 2019). Thus, early childhood center directors should consider exploring intervention options to combat the negative transactional spiral/developmental trajectory across multiple domains of health (physical, psychological, cognitive, etc.) for which all of the children in this sample are highly at risk.

Future Research

There are many future research inquiries that could extend or reinforce the initial findings within this study. First, we suggest recruiting a larger sample to include children with VI enrolled at traditional centers for greater generalizability (if possible). Additionally, we suggest further exploring the effects of onset and etiology on FMS. Within this study, we demonstrated descriptively that those who were born with VI performed better than those who acquired VI later on. These findings are not generalizable given the size of our sample. However, they warrant further inquiry. Finally, future research should examine the longitudinal effects of FMS delays on the developmental trajectory of children with and without VI.

Conclusion

The purpose of this study was to examine the FMS of preschool-aged children with and without VI. Children without VI showed the highest FMS levels when compared with children with VI. Children with VI in this sample exhibited profound developmental delays warranting the need for further inquiry and future intervention. These findings were novel as no previous literature reports FMS levels of preschool-aged children with VI. Although the findings fill a gap in the literature, future research should recruit a larger sample for greater generalizability.

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