

Children with Neurodevelopmental Disabilities

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This entry aimed to undertake an extensive exploration of the extent, range, and nature of research activities regarding the effect and emerging evidence in the field of physical activity interventions on cognitive development among children and youth (0–17.99 years) with neurodevelopmental disorders (NDD), and to help identify key gaps in research and determine precise research questions for future investigations. To carry out this scoping review, five electronic databases were searched. A total of 12,097 articles were retrieved via search efforts with an additional 93 articles identified from the identified review papers. Sixty articles were eligible for inclusion. The results of this scoping review revealed many positive key cognitive outcomes related to physical

activity including, but not limited to: focus, attention, self-control, cognitive process, and alertness. No studies reported a negative association between physical activity and cognitive outcomes. Based on the findings from this scoping review, physical activity appears to have a favorable impact on the cognitive outcomes of children and youth with NDD.

Keywords: physical activity ; cognition ; Neurodevelopmental Disorders ; Children and youth

1. Introduction

The prevalence of neurodevelopmental disabilities (NDD) among children continues to grow. In the United States and Canada, approximately 10–17% of the pediatric population (4–14 years) is diagnosed with NDD ^[1] including attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), cerebral palsy (CP), development coordination disorder (DCD), or fetal alcohol spectrum disorder (FASD), to name a few. NDD are widely defined as a “group of congenital or acquired long-term conditions that are attributed to impairment of the brain and/or neuromuscular system and create functional limitations” ^[2]. The impairments and dysfunctions associated with NDD are usually associated with significant consequences for children, families, and society ^{[3][4][5][6]}.

Physical activity provides numerous health benefits for children ^{[7][8]}. Due to physical and psychosocial limitations, children with NDD are often less active than their typically developing peers. Less frequent participation in physical activity may manifest as missed opportunities to positively impact various health outcomes including the development of motor skills, social learning, and mental wellness ^{[9][10][11][12][13][14][15][16]}. Families of children with NDD often report the desire to identify community-based physical activity programs aimed at stimulating cognitive development and improving self-control, autonomy, social integration, and quality of life. While this type of program has been found to be associated with a range of benefits for children, variations in research design, populations studied, intervention type, and outcomes measured have made determining the true effects of this type of program difficult.

To our knowledge, no in-depth review has been conducted to explore the existing literature regarding the multiple types of community-based physical activity programs for children with varieties of NDD, and the different types of outcomes studied. A scoping review of the literature was conducted to examine the impact of physical activity on the cognitive function of children with NDD, identify the most promising interventions, and clarify existing gaps and inconsistencies in the literature. More specifically, this manuscript aimed to: (a) investigate the extent, range, and nature of research activities regarding the effect and emerging evidence in the field of physical activity interventions on cognitive development among children and youth with NDD, and (b) help identify key gaps in research and determine precise research questions for future investigations. Collectively, this information will also help to determine the value of conducting further systematic reviews and meta-analyses.

2. Search Strategy

The following electronic databases were searched: PubMed, MEDLINE (EBSCOhost), CINAHL, PsycINFO, and ERIC (Education Resources Information Center). Search terms representing physical activity or specific activities such as exercise, recreation therapy, physical activity, and sport were combined with search terms representing NDD or specific conditions such as neurodevelopmental disorders, cerebral palsy, intellectual disability, autism spectrum disorder, and

fetal alcohol spectrum disorder. Controlled vocabulary was incorporated into the search strategy to increase the breadth and relevance of the articles retrieved. The searches were limited by date from 1995 to 2017. No limits were set on type of publication. Only English language articles were included. See [Appendix A](#) for a search strategy for each database.

3. Discussion

This comprehensive scoping review reports the impact of physical activity on the cognitive functions of children and youth with different types of NDD conditions: ASD, ADHD, CP, Down syndrome, intellectual disabilities, physical disabilities, behavioral and social disabilities, learning disabilities, and developmental coordination disorder (DCD). A number of cognitive function outcomes were explored: executive function including cognitive flexibility, cognitive control and working memory, attention, short- and long-term memory, learning, perceptual processing, and alertness.

Most studies reported improvement in their measured cognitive function outcomes. About half of the reported improvements were statistically significant. No studies reported negative impacts or symptom regression on cognition among child participants with NDD. The majority of studies used standardized measurement tools in order to assess the change in studied outcomes. This finding indicates the role of physical activity in the learning and development of a child with NDD. The major findings of this scoping review will be discussed in the following paragraphs.

Most of the included studies have been conducted with boys 6–12 years of age who were diagnosed with ADHD ($n = 23$, 38.3%). This finding certainly corresponds to the fact that the main challenges described are triggered in the context of school exposure, and ADHD incidence is much higher among boys than girls. This focus of interest indicates the importance of identifying effective interventions for school age children with NDD. Regarding gender, most studies focus on boys, which corresponds to the fact that boys are more often diagnosed with ADHD and ASD in comparison to girls; however, we cannot eliminate a possible gender bias with more boys willing to participate in these studies. While some studies reported small improvements in girls with NDD, additional work is needed to clarify the relationship between physical activity and this particular sub-population.

Among the 60 studies that were included in the present scoping review, the largest number of positive impacts of physical activity was found in studies of exercise interventions followed by equine-assisted therapy, then sports. Of these papers, the majority focused on children with ADHD and ASD, where attention and its sub-domains of focus and concentration were the most commonly measured cognitive function. This finding corresponds to the main concern in this population, especially in the school context ^{[17][18][19]}. In the case of ADHD, participation in high-intensity physical activity or exercise may increase the release of endorphins (which helps regulate mood, pleasure, and pain) and neurotransmitters like dopamine, norepinephrine, and serotonin levels (which positively affect focus and attention) ^[20]. Combined, these effects on the brain help increase alertness and reduce the craving for new stimuli, which are typical characteristics of children with ADHD. Similarly, with ASD, higher-intensity physical activity has been noted in the literature as an effective supplement to children's treatment regimens ^{[21][22][23]}. Studies show that moderate-to-vigorous physical activity is associated with decreases in self-stimulatory behaviors, hyperactivity, aggression, self-injury, and destructiveness ^[24]. Furthermore, as many children with ASD are at increased risk for weight gain, including regular physical activity in their daily routine may have beneficial effects ^{[25][26]}. The incorporation of animal therapy into the treatment of protocols of children with ADHD and ASD is well-received and its positive effects have been noted in other reviews ^{[27][28]}.

The type of NDD diagnosis and physical activity intervention were examined in this review. We found that children with ASD saw the most improvements in attention and that equine-therapy appeared to be the best type of activity to produce such changes. As for children with CP, most gains were reported in the attention domain, with aqua therapy and movement therapy serving as ideal activities to realize such improvements. Lastly, children with ADHD reported improvements in attention, with again, exercise and movement therapy serving as the preferred conduits to improved cognitive functions, memory, and development. The acquisition of such information is paramount to our understanding of which domains of cognitive function are most positively impacted by physical activity and by which types of activity exposures. Consequently, this information will assist with the creation of tailored physical activity programming for children with NDD based on their unique abilities.

Our findings confirm the ones from other literature reviews. Pontifex et al. ^[29] in their narrative review examined the role of physical activity in reducing barriers to learning in children with developmental disorders including ADHD and ASD. Findings indicated that both single bouts of activity and chronic physical activity were associated with improved classroom performance ^{[29][30]}. A meta-analysis of 22 articles by Tan et al. ^[30] found an overall small to medium effect of exercise on cognition. Their findings support the efficacy of exercise interventions in enhancing certain aspects of cognitive performance in individuals with ASD and/or ADHD. In another systematic review and meta-analysis of eight RCTs, Cerrillo-Urbina et al. ^[31] reported that short-term aerobic exercise, based on several aerobic intervention formats, seems to be

effective for mitigating symptoms such as attention, hyperactivity, impulsivity, anxiety, executive function, and social disorders in children with ADHD. However, to our knowledge, this scoping review is the first comprehensive review that explored the impacts of several types of physical activity interventions on all aspects of cognitive function for children with a variety of neurodevelopmental challenges.

3.1. Strengths and Limitations

The majority of papers included in this review were RCTs and quasi-experimental studies, which highlights the credibility of the overall evidence. In addition, having a research question that was broad in scope allowed us to investigate many aspects of the existing relevant research studies. Despite these strengths, there are several limitations of this review worth noting. First, most of the studies had small sample sizes (75% of studies included less than 43 participants) and the physical activity programs were short in duration (75% of studies had interventions less than 12 weeks). Second, most studies did not organize data collection by a person who was unaware of the intervention status, which makes the studies prone to different types of observation/report biases and Hawthorne effects (i.e., the change in behavior of study participants due to the awareness of being observed) [32][33]. Third, information was generally lacking regarding the child/family's satisfaction of the effect and the level that the positive impacts of physical activity could meet the specific needs of a child and family. Fourth, due to the vast variability in reporting interventions and results, informing best practice recommendations is not possible. Finally, although the current review considered solely English-language, peer-reviewed publications and academic gray literature, examining the international and non-academic gray literature may help to expand and deepen our understanding of physical activity on acquisition of new functions (cognitive and psychological) and learning among children with NDD.

3.2. Future Directions

Based on the findings of this scoping review, we have identified several areas for further investigations. High quality studies on the impact of physical activity on brain function among very young children (under 6 years) with NDD are appealing. Brain plasticity is maximal in young children [34][35]; therefore, interventions should target younger children instead of waiting for impairments to be revealed in light of the demands of the school classroom. More generally, specific research questions include determining the type of activities at different ages and which effect is expected on different types of outcomes. A more focused look at the relationship between physical activity and brain function across disability categories including the undertaking of further investigations into the development of physical literacy for long-term physical activity and its impact on brain health would also be of interest. Given that peer relationships become increasingly important from childhood to adolescence, additional research to explore the impact of physical activity on social inclusion and personal identity development for children with NDD is important. As well, investigating the level of child/family's satisfaction of the positive impacts is of paramount importance. Lastly, a rigorous systematic review and meta-analysis of RCTs that investigate the effects of physical activity on children and youth with NDD is warranted.

4. Conclusions

The findings of this scoping review highlight that physical activity may have a favorable impact on the cognitive outcomes of children and youth with NDD. Given these noted benefits, additional investigations are needed to help optimize the use of physical activity in the daily lives of children with NDD to not only support improved cognitive functions, but overall social integration and quality of life as well.

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