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RESEARCH ARTICLE

EVALUATING PHYSICAL FITNESS AND MOTOR SKILLS IN ELEMENTARY SCHOOL CHILDREN WITH ATTENTION DEFICIT HYPERACTIVE DISORDER: A PILOT STUDY

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ABSTRACT

Background: Attention Deficit Hyperactive Disorder (ADHD), is a neuro developmental disorder, which is defined by developmentally inappropriate symptoms of inattention, impulsiveness and behavioral over activity.
Objective: To assess motor skills and physical fitness in elementary school children with ADHD and compare them with typically developing children.
Methods: Nineteen (19) typically developing children and seventeen (17) ADHD children between 8 and 12 years were recruited as participants. Motor skills and physical fitness was measured using a battery of test: (1)muscle strength, muscle endurance, Sit and reach test,6 Minute walk test, step test, Single leg triple hop test, Ball throw test, Nine hole peg test.
Results: Independent t-tests were carried out between ADHD group and typically developing children on all the dependent variables. The analysis revealed statistical significance for all the dependent variables tested at $p<0.05$.
Conclusion: This pilot study concludes that the ADHD children has reduced motor skill abilities and physical fitness compared to typically developing children.

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INTRODUCTION

Attention Deficit Hyperactive Disorder (ADHD) is a disorder defined by developmentally inappropriate symptoms of inattention, impulsiveness and overactivity. It is considered as predominantly a childhood disorder but continues to manifest itself through adolescence and adulthood. As the knowledge base with regards to this disorder increases, its recognition and thus, its management strategies have also evolved. Worldwide the prevalence of ADHD has been documented at 5.3% to 20% (Moffitt and Melchior, 2007; Polanczyk *et al.,* 2007), while in India studies have reported a prevalence of 5.2% to 29.5% (Bhatia *et al.,* 1991; Mukhopadhyay *et al.*, 2003; Kaur *et al*., 2006). Furthermore, the prevalence of ADHD among school children, particularly 9-10 year olds, was found to be 11.32% and was higher among males (66.7%) as compared to females (33.3%). Interestingly it was observed that ADHD was more prevalent among children in a lower socio-economic group (16.33%) compared to a middle socio-economic group (6.84 %) (Venkata and Panicker, 2013). Overall children with ADHD have attention problems with all tasks and activities. They have problems sustaining attention in play and participating in everyday tasks, including conversations, lectures, or lengthy reading. They are forgetful, have poor time management, and fail to meet deadlines. ADHD children avoid or dislike tasks that require sustained mental effort, such as schoolwork or homework as well play which require team work, goal orientation and sustained activity. Neurophysiological evidence suggest that children with ADHD have an altered dopaminergic function, hypo-functioning of the mesocortical and nigrostriataldopamine branches (Sagvolden, *et al*., 2005). This aberrant functioning gives rise to the development of hyperactivity in novel situations, impulsiveness, deficient sustained attention, increased behavioral variability, disinhibition, clumsiness and "neurological soft signs". Children with ADHD are socially ostracized and consequently their participation in physical activity and/or play is considerably limited due to social immaturity (So and Oh, 2008). Their decreased participation in play, particularly 'team games' is only 50–60% as they

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experience rejection by their peers (Flicek, 1992; Guevremont and Dumas, 1994; Carlson and Mann, 2000). This rejection by their peers is primarily because of their behavior being aggressive, inflexible, controlling, intrusive, annoying and being inattentive and violating rules during sport/games. Accordingly, as they grow older they tend to fall further behind in terms of motor skills and fitness, and their confidence diminishes as a result. By elementary and middle school, most children with ADHD perform poorly in physical education classes, and may also have a poor physical self-image and perform below expectations academically.

Motor skills disorder may be first identified when a preschooler or kindergartner is unable to perform age-appropriate skills, such as buttoning buttons and catching a ball, or when an elementary school child struggles with writing or sports activities (Harvey and Reid, 2003). They lack bounce while walking and running, and get easily tired and exhausted than their peers. ADHD children were often described by parents and teachers as being distracted, unmotivated, disobedient, aggressive, destructive or uncooperative. However, careful clinical observations and testing of motor functions indicates that behaviour can be better understood as problems associated with poor motor control and movement coordination (Stray, 2004). Motor skill disorder in ADHD is also explained through neuroimaging studiesas structural and functional deviations are present in various brain areas such as prefrontal regions, pre motor area, basal ganglia, cerebellum, anterior cingulate, corpus callosum (Baumgardner *et al.,* 1996; Mostofsky *et al.*, 1998; Middleton and Strick, 2001; Haber, 2003; Lehericy *et al.,* 2004; Akkal *et al.,* 2007; Calzavara *et al.,* 2007; Parent and Parent, 2007; Shaw *et al.,* 2007; Qiu *et al.,* 2009). Furthermore, numerous studies have shown changes in dopamine level which are directly attributable to regulatory a role in motor functions (Nieoullon, 2002). Berquin *et al.,* 1998). Overall, evidence from these studies, albeit not directly tested suggests that children with ADHD will manifest with motor skill problems.

Attentional deficits have also been linked with aerobic fitness in a typically developing children. Interestingly, findings from cross-sectional investigations on aerobic fitness of typically developing pre-adolescent children have observed that lower-fit children exhibit deficient allocation of attentional resources, delays in information processes, and inefficient action monitoring (Hillman *et al.,* 2005; 2009; Pontifex *et al.,* 2011). If this is the case of typically developing children, then ADHD children who additionally exhibit difficulties with motor coordination and control should also manifest with fitness problems. However, the co-occurrence of poor motor performance and problems with fitness has received less attention in research compared to the attention for psychiatric comorbidities like depression etc. (Ellen *et al.,* 2009; Jyothsna, 2013). Motor and fitness problems are usually not part of assessments for ADHD and are typically not included in intervention programs (Gillberg and Kadesjo, 2003; Gillberg *et al.,* 2004; Sergeant *et al.,* 2006). However, a few studies have indirectly studied fitness in ADHD children but have focused on only one or two components of physical fitness. These studies were more interested in the effects of stimulant medication on VO2 max (Leger, *et al*., 1984), adipose tissue (Harvey and Reid, 1997) and heart rate (Ballard, 1977). These studies have suggested decrements aerobic fitness in children with ADHD (Harvey and Reid, 1997, Leger, *et al*., 1984). Interestingly, a review of the literature revealed no studies that had examined anaerobic performance or capacity (Harvey and Reid, 1997). Clearly, there is a lack of physical fitness research in children with ADHD. Given that awareness and knowledge with regards to this disorder is still in its infancy in India it is important that researchers comprehensively begin to study this physically, psychologically, and socially debilitating disorder, which far reaching implications in the development of a child; the effects of which are long lasting and are sustained through adulthood. Given the paucity of research, the purpose of this preliminary study was to assess motor skills and physical fitness in elementary school children with ADHD and compare them with typically developing peers.

MATERIALS AND METHODS

Participants

Thirty five children, ages 8-12 years were recruited as volunteers from a local public school. There were 19 typically developing children (8-12 years) and 16 ADHD children (8-12 years). The sample was a sample of convenience. ADHD children were identified through the school records. Once permission granted by the school, informed consent was obtained from all children and their parents. Children who were not willing to participate, with a history of musculoskeletal disorders and other neurological disorders (epilepsy, etc.), with a history of cardio-respiratory disorders, and children who were currently engaged on a regular basis in sports, were excluded from the study.

Outcome measures

Gross motor skill testing

1. Locomotor skills- Single leg triple hop test.
2. Object control skills- Seated medicine ball throw test.

Fine motor skill measures

1. 9-Hole Peg Test

Physical fitness test battery

1. Body composition- Weight, Height, BMI.
2. Muscle strength – Hand Grip strength.
3. Muscle Endurance -1 min curl up test.
4. Explosive strength - Vertical Jump test.
5. Flexibility- Sit and reach test
6. Aerobic capacity- 12 minute run/walk test
7. Anaerobic Capacity - Step test

Procedure

The study population were selected from a school of Delhi. Initially the school authorities were approached and the importance and procedure of this study were explained to them.

Table 1. Physical Characteristics

Physical characteristics	Number of subjects	Weight(kg)		HEIGHT(m)		BMI		AGE(years)	
		M±SD	RANGE	M±SD	RANGE	M±SD	RANGE	M±SD	RANGE
Typically developing children	19	33.23±6.95	23.3-44.6	1.36±0.06	1.23-1.44	17.84±3.25	13.37-22.44	9.05±0.91	8-12
ADHD children	17	38.86±10.94	24.1-57.7	1.39±0.07	1.26-1.52	19.88±4.51	14.69-26.86	9.44±1.26	8-12

The permission letter to recruit students from their school principal were obtained. The subjects with ADHD were recruited as diganosed by Medical Practioner- physician, paediatrician, psychiatrist, neurologist or clinical psychologist on the basis of psychological testing from school records. The subjects who meet the inclusion and exclusion criteria of the study were included. The subject who were willing to participate in the study were recruited and assent form and informed consent form were signed by children and parent of the child respectively. For comparison typically developing children were also recruited after getting consent and assent form signed from parent and child respectively. The ADHD children and typically developing children were assessed for motor skill and physical fitness. There were 9 stations made and the children were assessed, proper warm up and cool down periods were provided to ensure safety of the children.

Data reduction and Analysis

There were 17 ADHD Children and 19 typically developing children were recruited for this study and their physical characteristics has no significant difference between the two groups (Table 1). The data was analyzed through Graph Pad software 2016. The acquired data analyzed using independent t-test. The results of this study shows the difference between the typically developing children group & ADHD group is extremely statistical significant at 95% confidence level.

Gross motor skill

The typically developing children had covered higher distance in locomotor skill testing for Single Leg Triple Hop Test (Right Leg) (*M*=2.75, *SD*=0.59) than the ADHD children (*M*=1.74, *SD*=0.81), *P*=0.0001 and the typically developing children had covered more distance in locomotor skill testing for Single Leg Triple Hop Test (Left Leg) (*M* =2.58, *SD*=0.62) than the ADHD children (*M*=1.61, *SD*=0.79), *P*=0.0002. The ADHD children had covered less distance in object handling skill- medicine ball throw test (*M*=1.13, *SD*=0.22) compared to typically developing children (*M*=1.31, *SD*=0.23), *P*=0.02.

Fine motor skill

There is extremely statistical significant difference between the two groups, where the typically developing children completed the task earlier (for left hand-*M*=22.03, *SD*=2.20; for right hand nd- *M*=19.64, *SD*=1.73) than the ADHD children (for left hand - *M*=51.65, *SD*=4.27; for right hand - *M*=44.78, *SD*=3.66), *P*<0.0001.

Physical fitness test

Muscle strength

The hand grip strength for right hand was found to be greater in typically developing group (*M*=38.29, *SD*=5.51) than the ADHD children (*M*=31, *SD*=8.11), *P*<0.0031 whereas hand grip strength for left hand was found to be no significant statistical difference between the typically developing children (*M*=30.75, *SD*=6.30) and ADHD children (*M*=27.14, *SD*=9.65), *P*<0.19.

Muscle Endurance

The typically developing children performed better (*M*=17.42, *SD*=3.17) than the ADHD children (*M*=6.88, *SD*=4.03), *P*<0.19 in 1 minute curl up test.

Flexibility

The hamstring muscle flexibility was checked by sit and reach test where the typically developing children (*M*=29.69, *SD*=4.81) had more flexibility than the ADHD children (*M*=19.86, *SD*=4.12.), *P*<0.0001.

Vertical jump test

The leg explosive power of typically developing children (*M*=27.13, *SD*=4.08) was better than ADHD children (*M*=17.79, *SD*=5.14), *P*<0.0001.

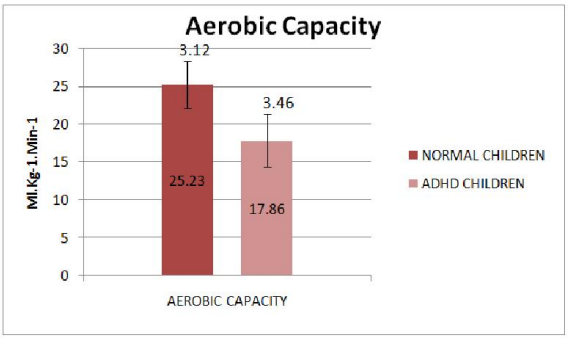

Figure 1. Aerobic Capacity of ADHD and typically developing (normal) children

Aerobic capacity

The typically developing children were able to run faster and cover more distance in 6 minute walk/run test (*M*=881.82, *SD*=135.68) compared to ADHD children (*M*=561.55, *SD*=150.52), *P*<0.0001 hence aerobic capacity (Figure 1), VO_2 Max of typically developing children (*M*=25.23, *SD*=3.12) was found to be higher than ADHD children (*M*=17.86, *SD*=3.46), *P*<0.0001.

Anaerobic capacity

The anaerobic capacity (Figure 2) of ADHD children (*M*=59.72, *SD*=14.96) was found to be reduced significantly

when compared to typically developing children (M=86.63, SD=24.53), P =0.0004.

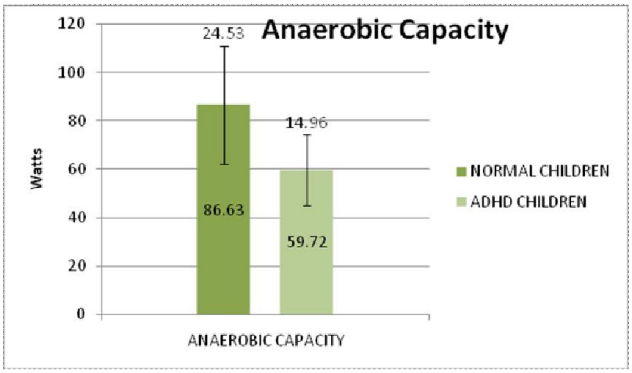

Figure 2. Anaerobic Capacity of ADHD and typically developing (normal) children

DISCUSSION

This study was conducted with the primary objective of assessing physical fitness and motor skills in elementary school children with ADHD and compare them to age-matched typically developing children. It was found that children with ADHD had significant deficits in their fitness levels as well as gross and fine motor skills as compared to their typically developing peers. The notion of physical activity and its benefits with regards to cognition and containing the severity of symptoms in ADHD children is not new (Etnier *et al*., 1997) however this is one of the few studies that has objectively documented deficits in skill and fitness levels compared to normal. Motor skill development is a critical dimension of the overall development of the young child and it is important to assess the present level of motor skill abilities of the child, particularly the child with ADHD to monitor the growth and development of the child. In this respect this study, assessed the gross and fine motor skills to identify children who may not be developing or progressing as expected or may be at risk for future problems. It was found that ninety three percent (93%) of the children with ADHD that were assessed had deficits in motor skills related to locomotion as well as in object control skills, when compared to typically developing children. Fine motor skill which is an essential requirement for school going children and requires the coordination of many physiological systems to produce precise movement such as writing was deficient in all the ADHD children who were recruited for this study. Motor skill levels and physical fitness have been found to be interrelated (Scott *et al*., 2007). Recent findings suggest that children with reduced levels of motor skills also demonstrated significantly poorer performance on important components of physical fitness, such as aerobic and anaerobic endurance (Faught *et al*., 2005; Scott *et al*., 2007; Cairney *et al*., 2007) and muscular strength, than their typically developing peers (Scott *et al*., 2007). In the current study, components of physical fitness such as aerobic and anaerobic capacity, muscle strength, muscle endurance, flexibility, and leg explosive strength were found to be reduced as compared to their typically developing peers. Physical fitness is considered to be a powerful marker of generalized health outcomes in children and adolescents. Studies of the relationship between physical fitness and overweight or obesity in young people have indicated that there is an inverse relationship between the two factors (Bovet *et al*., 2007). A low level of fitness has also been associated with diabetes as well as cardiovascular disease This study revealed that children with ADHD are less fit than their peers predisposing them to a greater extent to disease and health issues in their adult life. It is thus imperative that physical fitness specifically tested and addressed in a structured manner in children with ADHD. The development of motor skills and fitness is associated with cognitive development. Recently, the impacts of exercise on children's cognitive process have been assessed in cross-sectional studies which found that a higher level of aerobic fitness was associated with better interference control, a component of the executive control, in a task performance (Stroop Task) in children without disabilities (Buck *et al*., 2007). These authors had already shown that a high level of fitness was associated with parameters of attention, working memory, and speed response in children (Hillman *et al*., 2005). There is growing body of researches observed lower cardiorespiratory fitness relates to an increased occurrence of failures in sustained attention (Chaddock *et al*., 2011). The mechanisms underlying fitness-related deficits in sustained attention likely relate to differences in brain structure and function. Specifically, findings from cross-sectional investigations of aerobic fitness in preadolescent children have observed modulations in neuroelectric indices of cognition, with lower aerobic fitness being associated with deficits in response inhibition, reductions in the allocation of attentional resources, delays in the speed of information processing, and decreased integrity of action-monitoring processes (Hillman *et al*., 2005; 2009; Pontifex *et al*., 2011). Accordingly, poorer aerobic fitness may be associated with inefficient neural resource allocation resulting in more frequent and longer lapses of sustained attention. Beyond functional deficits, deficits in neural structures in the basal ganglia and hippocampus have also been observed in lower-fit children compared to higher-fit children along with poorer performance on inhibitory control and relational memory tasks, respectively (Chaddock *et al*., 2010a; 2010b).

Motor skills difficulties have been related to limited participation in physical activity (Bouffard *et al*., 1996). Thus, improvement in motor skills could be an important variable facilitating the sport participation for ADHD children. Many researchers had supported the increase in physical activity, increases cognitive domain (Verret *et al*., 2010). Buck *et al*. (2007) suggest that their findings add support to the beneficial effects of physical activity, or fitness level, on cognitive performance during development in preadolescent children. The current study should be considered as preliminary as the sample size was small and it was a sample of convenience and the children were selected from one setting.

Conclusion

Fitness and motor skill development are important components that contribute to a child's overall development. Deficits in these parameters lead to physical and psychological impairments that have long lasting ramifications that extend well into adulthood. In this study we found that children with

ADHD exhibited greater deficits compared to their peers, both in their ability to perform motor skills as well as their physical fitness. As motor skills and physical fitness are considered powerful markers of health outcome in children, it is suggested that schools place greater emphasises on structured exercise programs within their physical education (PE) programs. Importantly, given the results of this study wherein we found relatively greater deficits in children with ADHD, it is important to institute these measures to greater extent in these children. In addition, it is also well known that ADHD children demonstrate significant benefits in cognition and attention with exercise. As children with ADHD lack far behind their peers in all markers of development, a regular exercise program that addresses motor skills and fitness would immensely benefit these children, and thus should be incorporated into their play and/or exercise protocols. Currently, school PE programs do not include specific tests to evaluate motoric skills and fitness that are specific to the needs of ADHD children, and thus these deficits are completely ignored by PE instructors leading to a decreased participation in sports and play by these children, resulting in health disorders they can ill afford.

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REFERENCES

Akkal, D., Dum, R.P. and Strick, P.L. 2007. Supplementary motor area and presupplementary motor area: targets of basal ganglia and cerebellar output. *J Neurosci*, 27:10659–10673.

Ballard, J.E. 1977. The effects of methylphenidate during rest, exercise, and recovery upon the circulorespiratory responses of hyperactive children. Microform Publications.

Baumgardner, T.L., Singer, H.S. and Denckla, M.B. 1996. Corpus callosum morphology in children with Tourette syndrome and attention deficit hyperactivity disorder. *Neurology,* 47:1–6.

Berquin, P.C., Giedd, J.N., Jacobsen, L.K., Hamburger, S, D., Krain, A.L., Rapoport, J.L. and Castellanos, F.X. 1998. Cerebellum in attention-deficit hyperactivity disorder: a morphometric MRI study. *Neurology*, 50:1087–1093.

Bhatia, M.S., Nigam, V.R., Bohra, N. and Malik, S.C. 1991. Attention deficit disorder with hyperactivity among paediatric outpatients. *Journal of Child Psychology and Psychiatry and Allied Disciplines,* 32(2):297–306.

Bouffard, M., Watkinson, E. J., Thompson, L. P., Causgrove Dunn, J. L. and Romanow, S. K. E. 1996. A test of the activity deficit hypothesis with children with movement difficulties. *Adapted Physical Activity Quarterly*, 13:61-73.

Bovet P, Auguste R, Burdette H. 2007. Strong inverse association between physical fitness and overweight in adolescents: a large school-based survey. *Int J BehavNutr Phys Act*., 4:24. Available at: http://www.ijbnpa.org/content/4/1/24. DOI: 10.1186/1479-5868-4-24.

Buck, S. M., Hillman, C. H., & Castelli, D. M. 2007. The relation of aerobic fitness to stroop task performance in preadolescent children. *Medicine and Science in Sport and Exercise,* 40: 166-172.

Calzavara, R., Mailly. P. and Haber, S.N. 2007. Relationship between the corticostriatal terminals from areas 9 and 46, and those from area 8A, dorsal and rostral premotor cortex and area 24c: an anatomical substrate for cognition to action. *Eur J Neurosci.,* 26:2005–2024.

Castellanos, F.X., Giedd, J.N., Berquin, P.C., Walter, J.M., Sharp, W., Tran, T., Vaituzis, A.C., Blumenthal, J.D., Nelson, J., Bastain, T.M., Zijdenbos, A., Evans, A.C. and Rapoport, J.L. 2001. Quantitative brain magnetic resonance imaging in girls with attention-deficit/hyperactivity disorder. *Arch Gen Psychiatry*, 58:289–295. doi: 10.1001/archpsyc.58.3.289.

Chaddock L, Erickson KI, Prakash RS, Kim JS, Voss MW, VanPatter M, Pontifex MB, Raine LB, Konkel A, Hillman CH, Cohen NJ, Kramer AF. 2010a. A neuroimaging investigation of the association between aerobic fitness, hippocampal volume and memory performance in preadolescent children. *Brain Research*, 1358:172–183. [PubMed: 20735996]

Chaddock L, Erickson KI, Prakash RS, VanPatter M, Voss MW, Pontifex MB, Raine LB, Hillman CH, Kramer AF. 2010b. Basal ganglia volume is associated aerobic fitness in preadolescent children. *Developmental Neuroscience*. 32:249–256. [PubMed: 20693803]

Chaddock L, Pontifex MB, Hillman CH, Kramer AF. 2011. A review of the relation of aerobic fitness and physical activity to brain structure and function in children. *Journal of the International Neuropsychological Society*, 17:1–11. [PubMed: 21083962]

Denckla, M.B. and Rudel, R.G. 1978. Anomalies of motor development in hyperactive boys. *Ann Neurol*, 3:231–233. doi: 10.1002/ana.410030308.

Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., and Nowell, P. 1997. The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. *Journal of Sport and Exercise Psychology*, 19: 249-277

Faught BE, Hay JA, Cairney J, Flouris A. 2005. Increased risk for coronary vascular disease in children with developmental coordination disorder. *J Adolesc Health*, 37:376–380

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. 2009. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149-1160.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. 2007. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39, 175-191.

Fliers, E.A., Franke, B., Nanda N.J., Rommelse,L., Marieke, E. Altink, Cathelijne, J.M., Buschgens., Maria W.G., Sanden, N.V.D., Joseph A., Sergeant., Stephen V., Faraone and Buitelaar. J.K. 2009. Undertreatment of Motor Problems in Children with ADHD.*Child and Adolescent Mental Health*..doi: 10.1111/j.1475-3588.2009.00538.x

Gillberg, C. and Kadesjo, B. 2003. Why bother about clumsiness? The implications of having developmental coordination disorder (DCD). *Neural Plasticity*, 10: 59–68.

Gillberg, C., Gillberg, I.C., Rasmussen, P., Kadesjo, B., Soderstrom, H., Rastam, M., Johnson, M., Rothenberger, A., and Niklasson, L. 2004. Co-existing disorders in ADHD –implications for diagnosis and intervention. *European Child Adolescent Psychiatry*, 13 (Supplement 1): 180–192.

Guevremont, D.C. and Dumas, M.C. 1994. Peer relationship problems and disruptive behavior disorders. *Journal of Emotional and Behavioral Disorders*, 2(3):164–172.

Haber, S.N. 2003. The primate basal ganglia: parallel and integrative networks. *J Chem Neuro anat*., 26:317–330.

Haga M. 2009. Physical fitness in children with high motor competence is different from that in children with low motor competence. *Phys Ther*., 89:1089–1097

Harvey, W.J. and Reid, G. 1997. Motor performance of children with attention-deficit hyperactivity disorder: A preliminary investigation. *Adapted Physical Activity*, 14(Quarterly): 189-202.

Harvey, W.J. and Reid, G. 2003. Attention-Deficit/Hyperactivity Disorder: A Review of Research on Movement Skill Performance and Physical Fitness. *Adapted Physical Activity*, 20: 1-25.

Hillman, C. H., Castelli, D. M., and Buck, S. M. 2005. Aerobic fitness and neurocognitive function in healthy preadolescent children. *Medicine and Science in Sport and Exercise,* 37:1967-1974.[PubMed: 16286868]

Hillman, C.H., Buck, S.M., Themanson, J.R., Pontifex, M.B. and Castelli, D. 2009. Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. *Developmental Psychology*, 45:114–129. [PubMed: 19209995]

Kaur, P., Chavan, B.S. and Lata, S. 2006. Early intervention in developmental delay. *Indian Journal of Pediatrics*, 73(5):405–408.

Lehericy, S., Ducros, M., Krainik, A., Francois, C, Moortele, V.D., Ugurbil, K. and Kim, D.S. 2004. 3-D diffusion tensor axonal tracking shows distinct SMA and pre-SMA projections to the human striatum. *Cereb Cortex*, 14:1302–1309.

Leiner, H., Leiner, A. and Dow, R.S. 1989. Reappraising the cerebellum: what does the hindbrain contribute to the forebrain? *Behav Neurosci*, 103:998–1008. doi: 10.1037/0735-7044.103.5.998

Middleton, F.A. and Strick, P.L. 2001. A revised neuroanatomy of frontal-subcortical circuits. In: Lichter DG, Cummings JL, editors. Frontal-Subcortical Circuits in Psychiatric and Neurological Disorders. New York: Guilford; pp. 44–58.

Moffitt, T. E. and Melchior, M. 2007. Why does the worldwide prevalence of childhood attention deficit hyperactivity disorder matter? *American Journal of Psychiatry*, 164(6):856–858.

Mostofsky, S.H., Reiss, A.L., Lockhart, P. and Denckla, M.B. 1998. Evaluation of cerebellar size in attention-deficit hyperactivity disorder. *J Child Neurol*., 13(9):434-439.

Mukhopadhyay, M., Misra, S., Mitra, T. and Niyogi, P. 2003. Attention deficit hyperactivity disorder. *Indian Journal of Pediatrics*, 70(10):789–792.

Nieoullon, A. 2002. Dopamine and the regulation of cognition and attention. *ProgNeurobiol*. 67:53–83. doi: 10.1016/S0301-0082(02)00011-4.

Parent, M. and Parent, A. 2006. Single-axon tracing study of corticostriatal projections arising from primary motor cortex in primates. *J Comp Neurol*., 496:202–213.

Polanczyk, G, M., Lima, S.D., Horta, B.L., Biederman, J and Rohde, L.A. 2007. The worldwide prevalence of ADHD: a systematic review and metaregression analysis, *American Journal of Psychiatry*, 164(6):942–948.

Polatajko HJ, Mandich AD, Miller LT, Jennifer J. 2001. Cognitive Orientation to Daily Occupational Performance (CO-OP) Part II The Evidence. *Phys OccupTherPediatr*, 20(2-3):83-106.

Pontifex, M.B., Raine, L.B., Johnson, C.R., Chaddock, L, Voss, M.W., Cohen, N.J., Kramer, A.F. and Hillman, C.H. 2011. Cardiorespiratory fitness and the flexible modulation of cognitive control in preadolescent children. *Journal of Cognitive Neuroscience*, 23:1332–1345. [PubMed: 20521857]

Qiu, A., Crocetti, D., Adler, M., Mahone, E.M., Denckla MB, Miller MI, Mostofsky SH. 2009. Basal Ga nglia Volume and Shape in Children With Attention Deficit Hyperactivity Disorder. *Am J Psychiatry,* 166(1):74-82.

Rasmussen, P., Gillberg, C., Waldenstrom, E. andSvenson, B. 1983. Perceptual, motor and attentional deficits in seven-year-old children: Neurological and neurodevelopmental aspects. *Developmental Medicine and Child Neurology*, 25: 315-333.

Sagvolden, T., Johansen, E., Aase, H. and Russell, V. 2005. A dynamic developmental theory of attention-deficit/hyperactivity disorder (ADHD) predominantly hyperactive/impulsive and combined subtypes.*Behav Brain Sci*, 28:397–419. doi: 10.1017/S0140525X05000075.

Scott N, Alof V, Hultsch D, Meemann D. 2007. Physical fitness in children with developmental coordination disorder. *Res Q Exerc Sport*, 78:438–450

Sergeant, J.A., Piek, J.P. and Oosterlaan, J. 2006. ADHD and DCD: A relationship in need of research. *Human Movement Science*, 25: 76–89.

Stray, L.L., Stray, T. and Tonnessen, F.E. 2009. Motor function neurological assessment (MFNU) as an indicator of motor function problems in boys with ADHD. *Behav Brain Funct*, 5:22–27.

Suresh, K.P. and Chandrashekara S. 2012. Sample size estimation and power analysis for clinical research studies. *Journal of Human Reproductive Science*, 5(1):7-13.

Takken, T., Net V.D.J. and Helders, P.J. 2003. Relationship between functional ability and physical fitness in juvenile idiopathic arthritis patients. *ScandJRheumatol*.,32:174– 178

Venkata, J.K. and Panicker, A.S. 2013. Prevalence of Attention Deficit Hyperactivity Disorder in primary school children. *Indian J Psychiatry*, 55(4): 338–342.

Verret, C., Guay, M.C., Berthiaume, C., Gardiner, P. and Beliveau, L. 2010. A Physical Activity Program Improves Behavior and Cognitive Functions in Children With ADHD: An Exploratory Study. *Journal of Attention Disorders*, 16(1):71 –80.

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