Attention-Deficit/Hyperactivity Disorder: A Review of Research on Movement Skill Performance and Physical Fitness

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The purpose of this study was to present a comprehensive review of research on the movement performance and physical fitness of children with attention-deficit/hyperactivity disorder (ADHD) and offer research recommendations. Movement behaviors of children with ADHD were described on the basis of 49 empirical studies published between 1949 and 2002. Major results indicated that (a) children with ADHD are at risk for movement skill difficulties, (b) children with ADHD are at risk for poor levels of physical fitness, (c) comorbidity may exist between ADHD and developmental coordination disorder (DCD), and (d) few interventions have focused on movement performance and physical fitness of children with ADHD. Numerous reference citations for seminal review articles on ADHD are provided so that potential researchers or program planners might enter the vast ADHD literature with some ease.

Attention-deficit/hyperactivity disorder (ADHD) is a complex combination of developmental problems with important medical, educational, and social implications (Cantwell, 1996). Little information is available about conducting physical activity programs for persons with ADHD. Only one literature review focused on children with ADHD in physical activity (Churton, 1989), and only a few sources address physical education (e.g., Bishop & Beyer, 1995; Craft, 2000; Sherrill, 1998). Therefore, a comprehensive review of the movement performance and physical fitness of children with ADHD is justified as substantial changes have been made in ADHD (e.g., Stubbe, 2000a), and new physical activity studies have been conducted since 1989 (e.g., Harvey & Reid, 1997; Piek, Pitcher, & Hay, 1999; Yan & Thomas, 2002).

At least 50 textbooks and over 6,000 scientific articles are devoted to ADHD (Barkley, 1995), with different nomenclature used over time (Barkley, 1998).
Tannock (1998) suggested that a comprehensive review of ADHD and related knowledge domains was not feasible because of the sheer volume of published literature. Following is an overview of four issues of concern to all educators and researchers. Under each issue, we describe the particular relevance to adapted and general physical education.

**Issues**

**Definition and Symptomatology**

ADHD is defined in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR) of the American Psychiatric Association (APA, 2000) with five specified diagnostic criteria: (a) 6 to 12 behavioral symptoms must be identified; (b) symptoms must be evident before the age of 7 years; (c) behaviors must be exhibited in at least two different settings; (d) significant impairment in social, academic, or occupational functioning should be observed; and (e) symptoms should not be better explained by another disorder (APA, 2000). Children who demonstrate these symptoms are usually identified first by parents or teachers (APA, 2000) and subsequently referred to and assessed by clinical professionals (Reeve, 1990). Physical activity specialists should understand that there is a difference between children with ADHD and children who are simply overactive, because overactivity is only one indication of the disorder. In fact, the overactivity must be excessive and inappropriate to enter the definition of ADHD.

The DSM-IV-TR (APA, 2000) groups behavioral symptoms into two lists, representing clusters of inattention (e.g., often has difficulty sustaining attention in tasks or play activities) and hyperactivity-impulsivity (e.g., is often “on the go” or often acts as if “driven by a motor”). A child with ADHD must demonstrate six of nine symptoms for a diagnosis of the inattentive subtype, six of nine symptoms for a diagnosis of the hyperactive-impulsive subtype, or six symptoms from both inattention and hyperactivity-impulsivity for the combined subtype (APA, 2000). See Craft (2000) or Sherrill (1998) for explanations of the diagnostic criteria.

**Etiology**

The etiology of ADHD is unclear (Cantwell, 1996) and controversial (Stubbe, 2000b). Conceptual models about ADHD and associated causal factors depend upon the individual professional discipline and underlying assumptions of the clinician, researcher, or author. See Barkley (1997, 1998) for discussions of etiology. However, there is considerable agreement that ADHD should be considered a multidimensional disorder consisting of interacting neurological, genetic, and psychosocial causal factors (Tannock, 1998). Physical activity specialists should be aware of the probable biological basis for the lack of self-control that people with ADHD exhibit, which, in turn, may become more erratic in environments with decreasing amounts of social support (Barkley, 1997).

**Nomenclature and Classification**

Professionals and researchers should be cognizant of contemporary nomenclature and know that terminology changes over time. Nomenclature has been the subject
of considerable debate (McBurnett, Lahey, & Pfiffner, 1993), and there is little doubt that the many classification terms and subtyping terminology can lead to confusion. For example, there have been numerous classification terms which are further complicated by subtyping terminology (see Table 1). Comparing findings from studies based on different nomenclature must be done cautiously. McBurnett et al. (1993) offer a discussion of terminological comparisons using DSM over time. See Barkley (1998) for an excellent review on nomenclature and history of ADHD.

Two main terms are currently used, depending upon which of two classification systems are followed. North America is largely influenced by the DSM-IV-TR and the term ADHD. In Europe, the International Classification of Diseases (ICD-10) of the World Health Organization (WHO, 1992) has a large following, and the term hyperkinetic disorders (HKS) is used. A child identified with ADHD using DSM-IV-TR criteria may not be diagnosed with HKS using ICD-10 criteria. Tripp, Luk, Schaughency, and Singh (1999) suggested that identification with the ICD is more stringent and, therefore, fewer children are diagnosed with HKS than with ADHD. Both classification systems provide symptom lists for their diagnostic criteria. However, the ICD system specifies that a person must meet criteria for

<table>
<thead>
<tr>
<th>Manual</th>
<th>Classification Terms</th>
<th>Major Subtypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSM-I (1952)</td>
<td>None</td>
<td>None</td>
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<tr>
<td>DSM-II (1968)</td>
<td>Hyperkinetic Syndrome of childhood</td>
<td>None</td>
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<tr>
<td>DSM-III (1980)</td>
<td>Attention Deficit Disorder</td>
<td>ADDH, ADD-H</td>
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<td>DSM-III-R (1987)</td>
<td>Attention-Deficit Hyperactivity Disorder</td>
<td>Pervasive, situational</td>
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<tr>
<td>DSM-IV (1994)</td>
<td>Attention-Deficit Hyperactivity Disorder</td>
<td>Inattentive, hyperactive-impulsive, and combined types</td>
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</tr>
</tbody>
</table>

Note. DSM = Diagnostic and Statistical Manual of Mental Disorders published by the American Psychiatric Association, Washington, DC; ADDH = Attention Deficit Disorder with Hyperactivity; ADD-H = Attention Deficit Disorder without Hyperactivity; Situational subtype = only symptomatic at one setting or another (APA, 1987, p. 50); Pervasive subtype = symptomatic in at least two or more settings (APA, 1987, p. 50). See Hechtman (2000) for thorough review of diagnostic practices.
all three major diagnostic categories (attention, hyperactivity, and impulsivity), whereas the DSM system identifies persons who present symptom criteria of either inattention or hyperactivity-impulsivity categories or both. See Rasmussen and Gillberg (1999) for comparison of symptom lists.

Cultural differences also exist between Europe and North America, as some Europeans view ADHD as a rare disorder, with a prevalence rate of approximately 1%, affected by delinquency problems (Taylor et al., 1998). The disorder is considered to be more prevalent in North America with estimates ranging between 2% and 14% of elementary school-aged populations (Scahill & Schwab-Stone, 2000). See Taylor et al. (1998) for a discussion of cross-Atlantic classification differences.

Comorbidity, Treatment, and Developmental Course

There is no single method of diagnosis or intervention because there is no definitive cause of ADHD (Cantwell, 1996). Diagnosis of ADHD may be based upon combinations of age-appropriate symptoms, clinical tests, and observations (Hechtman, 2000). The diagnostic process should also include comorbidity (Cantwell, 1996) as there is a high probability of ADHD coexisting with one or more of the following disorders: developmental coordination disorder (DCD); oppositional defiant disorder; conduct disorder; anxiety, depression, and learning disabilities. See Pliszka (2000) and Rasmussen and Gillberg (1999) about comorbidity.

Multimodal treatment approaches are recommended for persons with ADHD (Mercugliano, 1999) because there is not one definitive cause of the disorder, and comorbidity is so frequent. For example, Damico, Damico, and Armstrong (1999) suggested combined intervention approaches that include pharmacological therapy, behavior management, cognitive-behavioral therapy, direct communicative interventions, and educational programs.

ADHD is considered a lifelong disorder because longitudinal research indicates that adults are also affected (Weiss & Hechtman, 1993). Previously, it was hypothesized to be only a childhood problem. The next decade promises identification studies that explore the age of onset criterion and symptomological changes with age (Barkley & Biederman, 1997). See Weiss and Hechtman (1993) and Silver (2000) for information about adult ADHD. Physical activity interventions and research programs should be developed with the understanding that children with ADHD may have at least one comorbid disorder (Szatmari, Offord, & Boyle, 1989) and the effects of ADHD may vary with the age of the participants (Barkley & Biederman, 1997).

Purpose

The purpose of this study was to present a comprehensive review of research on the movement performance and physical fitness of children with ADHD and offer research recommendations. The review and discussion attempt to answer two main questions: Is the movement performance of children with ADHD similar to their age- and gender-matched peers without disabilities? Do children with ADHD demonstrate similar levels of physical fitness when compared to their age- and gender-matched peers without disabilities?
Method

Search Strategies

Computer searches were conducted in the SPORTDiscus (1949- March, 2002), Current Contents/All Editions (Week 26, 1993-Week 07, 2002), ERIC (1966-February, 2002), MEDLINE (1966-March, 2002), and PsychINFO (1967-January, 2002) databases. Key words reflected a link to human movement science (e.g., motor, fitness, health, exercise, physiology, sport, recreation) and psychology, with special attention paid to chronology (e.g., attention deficit, attention deficit hyperactivity disorder, 1987-2002; attention deficit disorder, 1980-2002; hyperkinesis, hyperactivity, minimal brain dysfunction, 1949-2002). The footnote chasing approach was also used to identify studies that may have been missed (White, 1994).

Categorization

The categorization of studies was developed according to the taxonomy of movement skills by Burton and Miller (1998). Studies were placed into motor process and movement performance categories. Motor process studies were identified by dependent variables reflecting underlying internal factors believed to affect observable movement. These studies involved measures of perceptual-motor, psychomotor, or sensorimotor processes which can be referred to as “descriptors of motor processes rather than movement skills” (Burton & Miller, p. 44). For example, perceptual-motor processes were inferred from a finger tapping task in one study (Gordon & Kantor, 1979). Although the major purpose of this paper was to review the movement performance of children with ADHD, motor processes were discussed briefly to provide a global picture of movement behavior.

Movement performance is observable behavior. Thus, movement performance studies reflected an “observable act of moving” or a “goal-directed movement that can be described in terms of quantity or quality” (Burton & Miller, 1998, p. 43; Burton & Rodgerson, 2001). These studies were subdivided into four categories, reflecting different movement performance and research methods contexts: (a) retrospective views, (b) movement performance embedded in large descriptive studies, (c) skill performance, and (d) physical fitness. Retrospective studies have parents or teachers recall significant developmental events in the lives of children (e.g., Ottenbacher, 1979; Rasmussen & Gillberg, 1983). Movement performance embedded in large descriptive studies emphasize multiple dependent variables associated with general development. Movement behavior inferences from these studies are limited because very few movement skills or health-related variables are tested. Movement data embedded in larger studies have been noted also in DCD research (Sugden & Wright, 1998).

Researchers of skill performance usually assessed locomotor and object control skills as the main dependent variables. Physical fitness studies were defined by testing variables that measured health-related components of physical fitness including cardiorespiratory endurance, body composition, muscular strength and endurance, and flexibility (American College of Sports Medicine, ACSM, 2000). Physical fitness studies were placed in the movement performance category because fitness is a foundational component in the movement skills model of Burton and Miller (1998). For example, five of the eleven commonly assessed foundation
areas (e.g., body composition, body size and morphology, cardiovascular endurance, flexibility/range of motion, and muscular strength and endurance) reflect aspects of physical fitness.

Results and Discussion

Forty-nine studies, published between 1949 and 2002, were identified that examined the movement behavior of children with ADHD. The investigations were categorized as either motor processes (22) or movement performance (27). Movement performance studies included retrospective views (5), large descriptive studies (10), skill performance (10), and physical fitness (4). One study (Harvey & Reid, 1997) was included in the categories of skill performance and physical fitness, while another study (Doyle, Wallen, & Whitmont, 1995) was included in the retrospective views and skill performance categories. All studies in each category are identified in the reference list.²

Motor Processes

The motor processes of children with ADHD have been examined in studies that emphasize sensorimotor, motor control, and fine motor variables. Sensorimotor investigations tend to minimize gross motor output but highlight sensory or perceptual output. For example, tasks of visual motor performance (Cakirpaloglu & Radil, 1992; Conners & Delamater, 1980; Conrad, Dworkin, Shai, & Tobiessen, 1971; Korkman & Pesonen, 1994; Millichap, Aymat, Sturgis, Larsen, & Egan, 1968) and finger tapping (Gordon & Kantor, 1979) have been used to measure motor processes of males with ADHD. While contributing to our overall understanding of ADHD, the implications for physical activity curricula and instruction are not always obvious, given that the assessment tasks are quite distinct from usual ones in physical education.

A number of motor process studies have also explored aspects of motor control. Boys with ADHD have been linked to motor overflow (Denckla, Rudel, Chapman, & Krieger, 1985; Denckla & Rudel, 1978), impaired timing of motor responses (Hefley & Gorman, 1986; Rubia, Taylor, Taylor, & Sergeant, 1999; Werry, Elkind, & Reeves, 1987; Yan & Thomas, 2002), and motor soft signs (Denckla & Rudel, 1978; McMahon & Greenberg, 1977; Reeves, Werry, Elkind, & Zametkin, 1987; Sandberg, Rutter, & Taylor, 1978). In a recent motor control study (Yan & Thomas, 2002), children with ADHD took more time than children without ADHD to complete rapid arm aiming movements, with more variable speed and accuracy of the arm movements. Yan and Thomas (2002) suggested that children with ADHD use more on-line corrections when performing accuracy tasks in comparison to their peers without ADHD. It would appear that additional research is necessary to investigate aspects of motor control. While such studies often do not employ ecologically-valid tasks from the viewpoint of adapted physical activity specialists, collectively these investigations may shed light on unique motor control strategies and the overall motor behaviour associated with ADHD.

Poor motor coordination has been suggested as a condition experienced by many children with ADHD (Conners, Rothschild, Eisenberg, Stone-Schwartz, & Robinson, 1969; Gillberg, Carlstrom, Rasmussen, & Waldenstrom, 1983; Hefley & Gorman, 1986; Knights & Hinton, 1969; Palkes, Stewart, & Kahana, 1968;
The term *motor coordination* may be misleading, as the identified studies were usually based on neuropsychological tests that required fine motor skill performance. Motor skills may be classified into fine and gross motor skills by the precision of movement (Burton & Miller, 1998). The occasional confusion between fine and gross motor skills was underscored when the first author asked a renowned psychiatrist, a specialist for children with ADHD, what physical educators could do to help children with ADHD improve their gross motor skills. “Teach them how to hold a pencil” was the response. While Szatmari and Taylor (1984) also stated that coordinated finger movements reflect skill acquisition, they questioned the clinical utility of this type of neurodevelopmental sign. Thus, the researchers might have been more correct to describe their findings as suggesting that children with ADHD have poor fine motor coordination rather than a general motor coordination deficit.

**Movement Performance**

*Retrospective Views.* Retrospective studies usually report teacher (Ottenbacher, 1979) and parent observations of poor movement skills in children with ADHD. For example, mothers reported their children performed poorly in sports, gymnastics, and fine movement skills (Stewart, Pitts, Craig, & Dieruf, 1966) while other parents have perceived their children as clumsy (Rasmussen & Gillberg, 1983; Szatmari et al., 1989).

Although the observations of both parents and teachers are invaluable, conclusions are usually based in a context of memory that is susceptible to decay and alteration (Offer, Kaiz, Howard, & Bennett, 2000). These perceptions can also be imprecise as excessive activity may overshadow real problems of coordination (Keogh, 1978). Furthermore, an underlying assumption of these studies is that most parents possess adequate amounts of motor development knowledge for comparison purposes. Moreover, Rasmussen and Gillberg (1983) asked parents to answer only one question: “How would you describe your child’s gross motor control (e.g., movement control in activities like walking, running, climbing, hopping on one leg)? Is it average (0), Better than average (1), Somewhat clumsy (2), or Awkward (3)” (p. 128). Doyle, Wallen, and Whitmont (1995) reported that parents underrated their children’s performance on a single question in comparison to the actual results obtained on the Bruininks-Oseretsky Test of Motor Proficiency or BOTMP (Bruininks, 1978). While potentially informative, retrospective views hardly represent a comprehensive analysis of movement behavior.

Empirical investigations should be conducted in concert with retrospective research to understand the factors underlying the perceptions of parents in relation to their children’s movement skills. For example, what is the role of social factors (e.g., socioeconomic level, cultural background, gender, age, etc.) in parental observations? Are the parents proficient movers or do they also experience problems of movement behavior? How important is physical activity in the family context? Such research may explore the ability of parents to comment on the skill proficiency of their children and their ability and experience in fostering skill acquisition. Furthermore, children with ADHD should be asked about their own perceptions of their movement skill proficiency and involvement in play, physical activity, and sports. Qualitative research studies have been recommended to document the health-related behaviors of children with ADHD (Kendall, 1997), and these types of
investigations could provide rich and thick personal descriptions about the movement skills and experience of children with ADHD.

**Movement Performance Embedded in Large Descriptive Studies.** Movement performance has been assessed in large descriptive studies where the research focus is broad, covering multiple developmental factors, but the examination of specific movement skills is rather narrow. For example, Ho et al. (1996) collected a wealth of information about children (e.g., developmental history, sociodemographic data, family relationship, intelligence, reading ability, academic performance, motor activity level, attention performance, neurological status, and motor clumsiness), but movement performance was represented by catching, only one of 39 testing items. In addition, only two items (e.g., catching and rolling a tennis ball by foot) were used to assess movement performance of children with ADHD in several studies (e.g., Ho et al., 1996; Luk, Leung, & Yuen, 1991; Tripp & Luk, 1997).

A number of large descriptive studies have compared the movement performance of children with and without ADHD. Tripp and Luk (1997) reported that children with ADHD, ages 5.5 to 12.9 years, demonstrated no significant differences on ball catching and rolling a tennis ball by the foot, while Ho et al. (1996) found that 7-year-old children with ADHD performed significantly poorer when catching a tennis ball. Furthermore, in a longitudinal study (Moffitt, 1990) of children from the ages 3 to 15 years, the scores of males with ADHD were significantly lower on the Bayley Scale (Bayley, 1969) at 3 years of age and on the McCarthy Motor Scale (McCarthy, 1972) at 5 years of age than the control groups.

Longitudinal research indicates that children with comorbid ADHD and DCD, known in Scandinavian countries as deficits in attention, motor control, and perception or DAMP (Blondis, 1999), are at risk for movement difficulties in both fine and gross movement skills (Gillberg, 1985; Gillberg, Gillberg, & Groth, 1989; Hellgren, Gillberg, Gillberg, & Enkerskog, 1993; Rasmussen, Gillberg, Waldenstrom, & Svenson, 1983). However, these large epidemiological studies have focused mainly on the prevalence of ADHD with DCD (Kadesjo & Gillberg, 1998) or the motor profiles of children with DAMP as measured by a single neurodevelopmental screening test (Gillberg, 1985; Gillberg et al., 1989; Hellgren et al., 1993; Rasmussen et al., 1983), rather than on a comprehensive observation of their movement performance.

For example, Rasmussen et al. (1983) tested 112 children, ranging from 6.8 to 8.3 years, on a neurodevelopmental screening test (Gillberg, 1983). Fine and gross movement skills were hopping on one leg, standing on one leg, walking on lateral sides of the feet, supination and pronation of both forearms (diadochokinesis), cutting out a paper circle, a labyrinth test, observance of choreatiform movements, a pencil grip, walking on tiptoe for 20 paces, and hopping with both feet together. Children with DAMP demonstrated significantly lower scores than children without disabilities over the course of a 10-year period. The actual percentage of persons with DAMP who demonstrated poor movement performance dropped from 62% (Rasmussen et al., 1983) to 30% after 3 years (Gillberg, 1985), 25% after 6 years (Gillberg et al., 1989), and 20% after 10 years (Hellgren et al., 1993). These results indicate that some children with DAMP may experience movement difficulties into early adulthood. However, it should be noted that misclassification rates were approximately 14% (Rasmussen et al., 1983), and interrater reliability for overall clumsiness was only .55 (Gillberg, 1985). Because the same test items were used over 10 years, test demands may have declined with development, partly
accounting for the fewer individuals being classified as poor in motor performance. While the developmental validity of the testing methods can be questioned, the 20% of children who demonstrated movement difficulties into late adolescence must have had serious movement problems. These findings are the only empirical evidence that supports the notion that movement performance difficulties can be lifelong in persons with both ADHD and DCD.

Kadesjo and Gillberg (1998) also assessed 409 seven-year-old children on the same neurodevelopmental screening test and a physical education motor skills test, the Folke Bernadotte test (Bille et al., 1985 as cited in Kadesjo & Gillberg, 1998). The testing items for the physical education assessment were not provided. Results indicated that 6.6% of the sample had DAMP and 50% of children with ADHD also had DCD.

In general, evidence from the large descriptive studies point to movement performance difficulties associated with ADHD. However, few movement skills are typically assessed, and these are usually unrelated to physical activity curricula. Practitioners and researchers require more detailed information to meet the needs of individuals with ADHD.

**Skill Performance.** Problems with skill performance have been linked also to children with ADHD between the ages of 5 to 18 years (see Table 2). These studies can be clustered into three groups: (a) intergroup comparison, (b) intragroup comparison, and (c) intervention effectiveness.

Intergroup comparison research assesses the movement skills of children with ADHD in relation to norms or control groups. Beyer (1999) tested 112 males on items from the long form of the BOTMP. Boys with ADHD \( (N = 56) \) receiving stimulant medication performed significantly below their age-matched male peers with a learning disability \( (N = 56) \), who were not receiving stimulant medication, on four items (bilateral coordination, strength, visual motor coordination, and upper limb speed and dexterity). Significant differences were not found between the groups for balance, upper limb coordination, and response speed.

Doyle et al. (1995) used the short form of the BOTMP to test 38 children with ADHD. In contrast to Beyer (1999), they found that most participants performed movement skills significantly better than the age and gender norms provided in the BOTMP. However, Bruininks recommended the short form of the BOTMP be used as “a brief survey of general motor proficiency” (p. 13), or a screening instrument, because it is not as detailed as the long form. The results of Beyer (1999), perhaps, should be accorded higher relevance.

The balancing skills of children with ADHD have also been investigated in several studies. Piek et al. (1999) tested 48 males on both the Movement ABC, or MABC (Henderson & Sugden, 1992) and the Test of Kinaesthetic Sensitivity (Lazlo & Bairstow, 1985, as cited in Piek et al., 1999). In comparison to age-matched peers, overall balance scores were significantly lower for boys with ADHD-C (combined subtype), while manual dexterity scores on the MABC were significantly lower for boys with ADHD-PI (predominantly-inattentive subtype). There were no significant differences between any of the groups on the Test of Kinaesthetic Sensitivity.

Wade (1976) compared balance skills of 12 children with ADHD and 12 children without ADHD on a stabilometer task. While no statistical comparisons were performed, children with ADHD spent less time balancing when compared to their age- and weight-matched peers without a disability.
<table>
<thead>
<tr>
<th>Study</th>
<th>Purpose</th>
<th>Sample</th>
<th>Statistical analysis</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beyer (1999)</td>
<td>Compared movement skills of boys with ADHD and boys with LD</td>
<td>112 boys: ADHD = 56, taking Ritalin; LD = 56, no medication; 7-12 years; DSM-IV</td>
<td>MANOVA, ANOVA</td>
<td>Significant multivariate age ( (p &lt; .001) ) and condition ( (p &lt; .001) ) main effects were found on the BOTMP-LF. ANOVAs revealed boys with ADHD performed bilateral coordination ( (p &lt; .001) ), strength ( (p &lt; .001) ), visual motor coordination ( (p &lt; .001) ), and upper limb speed and dexterity ( (p &lt; .001) ) significantly worse than their peers with LD.</td>
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<td>Doyle et al. (1995)</td>
<td>Examined movement skills of children with ADHD and parental perceptions about their children’s skills</td>
<td>38 children: 33 boys, 5 girls; 7-12 years; DSM-III-R; stimulant medication use was variable</td>
<td>multiple independent ( t ) tests</td>
<td>82% of children with ADHD performed gross motor skills above the norms of the BOTMP-SF. Parents underrated the movement skill performance of their children with the use of 5-point Likert scale.</td>
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<td>Wade (1976)</td>
<td>Described differences on stabilometer task between children with and without ADHD and examined the effects of Ritalin on children with ADHD performing a stabilometer task</td>
<td>24 children: 12 = ND; 12 = hyperactive; 7.7-11.8 years; genders not reported; diagnostic framework not reported; stimulant medication taken</td>
<td>descriptive statistics</td>
<td>Children without a disability spent, on the average, more time on the static balancing task and performed more consistently than children with ADHD.</td>
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<td>Reference</td>
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<td>Sample Description</td>
<td>Method</td>
<td>Results</td>
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<td>Harvey &amp; Reid (1997)</td>
<td>Described fundamental movement skills and fitness conditions of children with ADHD</td>
<td>19 children: 17 boys, 2 girls; 5-12 years; DSM-III-R; 89% of sample took stimulant medication</td>
<td>Descriptive statistics, graphs</td>
<td>Children with ADHD performed locomotor skills (22.3 percentile) and object control skills (33.4 percentile) below the 35th percentile when compared to the age-matched norms of the TGMD.</td>
</tr>
<tr>
<td>Piek et al. (1999)</td>
<td>Investigated movement skills and kinaesthetic processes of boys with and without ADHD</td>
<td>48 boys: 16 = ADHD-PI; 16 = ADHD-C; 16 = ND; matched on age &amp; verbal IQ; 8.7-11.7 years; DSM-IV; 8 children from ADHD-C received stimulant medication</td>
<td>MANOVA, ANOVA</td>
<td>Intragroup Comparison Boys with ADHD (ADHD-PI, ADHD-C) performed significantly poorer ($p &lt; .002$) on the MABC than boys without disabilities. In comparison with the other groups, boys with ADHD-PI demonstrated significantly worse manual dexterity skills ($p &lt; .01$) while boys with ADHD-C demonstrated significantly worse balance skills ($p &lt; .01$).</td>
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<tr>
<td>Miyahara et al. (1995)</td>
<td>Identified movement and behavioral subtypes of HKS while estimating the comorbidity of HKS with DCD</td>
<td>23 children: 21 boys, 2 girls; 4-12 years; diagnostic framework for HKS from a German psychiatric textbook; stimulant medications taken</td>
<td>Cluster analyses, ANOVA</td>
<td>Significant univariate results were found between the free-from-severe motor impairment and manual incoordination motor clusters on manual dexterity ($p &lt; .01$) and balance ($p &lt; .01$) subtests of the MABC. 52% of the sample, or 12 out of 23 participants, fell in the manual incoordination subtype and were thus considered as having DCD.</td>
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(continued)
Kaplan et al. (1998) described comorbidity between DCD, ADHD, and RD. Of the 162 participants with comorbidity, 47 children had no disabilities. There were pure cases of ADHD (N = 8), DCD (N = 26), and RD (N = 19). Comorbidity was identified for ADHD/RD (N = 7), ADHD/DCD (N = 10), DCD/RD (N = 22), and ADHD/DCD/RD (N = 23).

Miyahara et al. (2001) examined the severity of HKS behaviors and comorbidity between HKS and DCD from school, support group, and hospital sample sources. Children with HKS, attending a school, were rated with significantly greater conduct problems (p < .02) than their hospitalized peers with HKS and greater hyperactive behaviors (p < .09) when compared to other peers with HKS from a support group. No significant differences were found between the groups on the MABC. Substantial amounts of overlap between HKS and DCD were found at the school (35%), support group (54%), and hospital (55%).

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<td>Kaplan et al.</td>
<td>Described comorbidity between DCD, ADHD, and RD</td>
<td>162 children: Specific age and gender information was not provided. However, the participants were selected because complete data were available from an initial sample of 379 children; 169 boys, 55 girls = ADHD + LD; 105 boys, 50 girls = ND; 8-18 years; DSM-III-R; Medication not reported</td>
<td>Descriptive statistics, Pearson correlation coefficients, $\chi^2$, ANOVA</td>
<td>Assessment instruments were the BOTMP, MABC, and an initial version of the DCDQ. Of the 162 participants with comorbidity, 47 children had no disabilities. There were pure cases of ADHD (N = 8), DCD (N = 26), and RD (N = 19). Comorbidity was identified for ADHD/RD (N = 7), ADHD/DCD (N = 10), DCD/RD (N = 22), and ADHD/DCD/RD (N = 23).</td>
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<td>ANOVA</td>
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### Intervention Effectiveness

<table>
<thead>
<tr>
<th>Study</th>
<th>Description</th>
<th>Sample Size, Ages</th>
<th>Outcome Measures</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hodge et al. (1999)</td>
<td>Examined the effects of warm-up activities on fundamental movement skill performance of children with LD + ADHD</td>
<td>46 children: 36 boys; 10 girls; 9-11 years; diagnostic framework not reported; medications were not reported</td>
<td>Two-way factorial ANOVAs (group skill x gender)</td>
<td>Children with ADHD (visual imagery warm-up condition) demonstrated significantly better throwing accuracy ((p &lt; .001)) than their peers who participated in task-specific warm-up or no warm-up conditions. No performance differences were found between the groups on a timed 40 yd-dash and a ball catching task. No main effects for gender or interaction effects were found.</td>
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<td>Wade (1976)</td>
<td>Described differences on stabilometer task between children with and without ADHD and examined the effects of Ritalin on children with ADHD performing a stabilometer task</td>
<td>24 children: 12 = ND; 12 = hyperactive; 7.7-11.8 years; genders not reported; diagnostic framework not reported; stimulant medication taken</td>
<td>ANOVA</td>
<td>The static balance of children with ADHD on the stabilometer improved significantly ((p &lt; .01)) when methylphenidate was being used.</td>
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<td>Pelham et al. (1990)</td>
<td>Examined the effects of methylphenidate on the attention and baseball skills of boys with ADHD</td>
<td>17 boys: 7.8-9.9 years; DSM-III-R; Stimulant medications taken</td>
<td>MANOVA</td>
<td>The attention of boys with ADHD, when medicated with methylphenidate, improved significantly during baseball games ((p &lt; .001)). However, their baseball skills did not improve.</td>
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</table>

The quality of movement skill patterns of children with ADHD, most of whom were taking stimulant medication, has been described as “below average” (Harvey & Reid, 1997). After testing 19 children with ADHD on the Test of Gross Motor Development or TGMD (Ulrich, 1985), Harvey and Reid reported that the children performed locomotor and object control skills below the 35th percentile when compared to age-matched norms.

Other studies have explored intragroup comparisons. Piek et al. (1999) found that both overall balance and manual dexterity scores on the MABC were significantly lower for boys with ADHD-C (combined subtype) when compared to boys with ADHD-PI (predominantly-inattentive subtype). Miyahara, Möbs, and Doll-Tepper (1995) tested 23 children with hyperkinetic disorders (HKS) on the MABC and then performed cluster analyses that revealed two motor subtypes: “free from severe motor incoordination” and “manual incoordination.” Manual dexterity and overall balance significantly distinguished between the two different motor subtypes. No performance differences were found between the two groups in ball catching.

Two other studies also employed an intragroup group approach and focused on the comorbidity of HKS or ADHD with DCD. The first study by Miyahara, Möbs, and Doll-Tepper (2001) examined the overlap between HKS and DCD by the performance on the MABC of 47 children with HKS. Considerable overlap between HKS and DCD was noted in the school (35%), support group (54%), and the hospital (55%) samples.

The second comorbidity study assessed 162 children with and without ADHD (Kaplan, Wilson, Dewey, & Crawford, 1998). Thirty-three percent met criteria for one disorder only. Of these, 5% had ADHD, 16% had DCD, and 12% had a reading disability (RD). Twenty-four percent met the criteria for two disorders. Of these, 14% had DCD and RD, 6% had ADHD and DCD, and 4% had ADHD and RD. Overall, comorbidity of ADHD, DCD, and RD was reported for 14% of the children. These figures suggest that the overlap between ADHD and DCD may be substantial. Future research should explore this comorbid relationship to determine if the precise movement difficulties are similar in the comorbid condition and when they occur in isolation. In addition, do comorbid or singular cases respond to intervention similarly? (Henderson & Henderson, 2002).

Treatment interventions related to movement performance in children with ADHD have also been investigated. Hodge, Murata, and Porretta (1999) examined the effects of three different preparatory conditions on the skills of throwing for accuracy, ball catching, and running for 46 children with ADHD. The preparatory conditions were no warm-up, a task-specific warm-up, and mental preparation or visual imagery that were carried out during the first 5 min of a single 60 to 90 min long testing session. This was a randomized posttest-only control group design where participants were randomly assigned to one of the three groups. The participants performed (a) five trials of throwing a beanbag at a target from a distance of 15 ft (4.57 m), (b) five trials of catching a sponge ball tossed from 6 ft (1.83 m), and (c) two 40-yd dashes (36.6 m). Throwing accuracy was significantly better in the visual imagery group when compared to the other groups. Significant differences were not found between the groups on the ball catching task and the dash. There were no main effects of gender or interactions.

Wade (1976) tested the effects of methylphenidate (Ritalin) on the balance skills of 12 children with ADHD with the use of the stabilometer task in a counterbalanced and placebo-controlled experiment. There was a 3-week time delay
between placebo and medication conditions. The balance skills of the children improved significantly during the medication condition.

Pelham et al. (1990) examined the effects of methylphenidate on attention and baseball skills of 17 boys with ADHD in a double-blind and placebo-controlled study. The attention of the boys improved significantly while playing baseball, but their baseball skills did not.

We should investigate the movement performance and physical activity experiences of children with ADHD from a number of different perspectives. Longitudinal studies need to be conducted, because movement performance changes over age have not been explored. We also know little about the physical activity patterns of children with ADHD and influencing factors. Research should be conducted on the efficacy of these interventions in enhancing movement performance and skill acquisition. Because pharmacological treatment interventions are not always effective for children with ADHD (Wilens & Spencer, 2000), optimal intervention techniques should be examined for children on and off medication. Furthermore, as self-regulation seems to be a problem for children with ADHD (Barkley, 1997), future research should address the effectiveness of self-regulation strategies in movement performance. Even at a descriptive level, we know little about the movement performance of children with ADHD since the most commonly used tests, the BOTMP and MABC, are quite limited in the number of movement skills assessed and may not be relevant to top down programming (Block, 2000).

**Physical Fitness.** Few studies have focused on the physical fitness of children with ADHD, although related phenomena such as heart rate (HR) have been investigated. For example, methylphenidate significantly elevates HR during rest (Porges, Walter, Korb, & Sprague, 1975). However, resting HR may be affected by interactions between stimulant medication dosage and the amount of time after ingestion. Kelly, Rapport, and DuPaul (1988) stated the amount of ingested medication may elevate posttest resting HR values on tests of attention. They suggested that premedication HR may also affect postmedication resting HR and the premedication resting HR value may be used as a covariate. See Kelly et al. for a thorough discussion about the effects of stimulants upon resting HR.

Other studies have more specifically explored the physical fitness of children with ADHD between the ages of 5 to 12 years (see Table 3). Boileau, Ballard, Sprague, Sleator, and Massey (1977) found the HRs of 20 children with ADHD were elevated both at rest and during a 5-min submaximal treadmill walk, when medicated with methylphenidate compared to a placebo condition. Oxygen consumption was also significantly lower during the exercise condition when the children were medicated. Thus, medication has an effect on physical fitness assessment.

Ballard (1977) conducted one of the most comprehensive investigations on health-related fitness of children with ADHD who were all receiving stimulant medication. Twenty-seven children with ADHD demonstrated significantly higher levels of body fat, with significantly higher blood pressure and HRs at rest, exercise, and recovery conditions when compared to 23 children without disabilities.

Harvey and Reid (1997) found similar results in their physical fitness field testing. Compared to normative data, 19 children with ADHD, most of whom were taking stimulant medication, demonstrated high levels of adipose tissue (75th percentile). Performance was below the 25th percentile on a $\text{VO}_2\text{max}$ field test (Leger, Lambert, Goulet, Rowan, & Dinelle, 1984), a shuttle run test (CAHPER, 1980),
### Table 3  Physical Fitness

<table>
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<tr>
<th>Study</th>
<th>Purpose</th>
<th>N</th>
<th>Statistical analysis</th>
<th>Findings</th>
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<tr>
<td>Ballard (1977)</td>
<td>Examined the effects of Ritalin on the health-related fitness of children with ADHD under rest, a submaximal treadmill walk, and recovery conditions</td>
<td>50 children: 27 = ADHD (24 boys, 3 girls); 23 = ND (19 boys, 4 girls); 7-13 years; diagnostic framework not reported; stimulant medication</td>
<td>MANOVA, ANOVA</td>
<td>No differences in weight, height, and lean body mass between children with ADHD and controls. Children with ADHD had significantly more body fat ($p &lt; .02$) and demonstrated increased heart rates and mean blood pressure at rest ($p &lt; .01, .01$)<em>, exercise ($p &lt; .01, .03$)</em>, and recovery ($p &lt; .01, .003$)* conditions.</td>
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<tr>
<td>Boileau et al. (1977)</td>
<td>Examined the effect of Ritalin on the heart rates and oxygen consumption ($\text{VO}_2$) of children with ADHD during rest and a submaximal treadmill walk condition for children with ADHD</td>
<td>20 children: 17 boys, 3 girls; 4-12 years; diagnostic framework not reported; stimulant medication</td>
<td>ANOVA</td>
<td>Heart rates of children with ADHD were significantly higher during rest ($p &lt; .01$) and exercise ($p &lt; .01$) when compared to placebo conditions. $\text{VO}_2$ during exercise was significantly lower ($p &lt; .01$) for the children in the medication condition.</td>
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<tr>
<td>Study</td>
<td>Description</td>
<td>Sample Characteristics</td>
<td>Methods</td>
<td>Findings</td>
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<tr>
<td>Harvey &amp; Reid (1997)</td>
<td>Described fundamental movement skills and fitness conditions of children with ADHD</td>
<td>19 children: 17 boys, 2 girls; 5-12 years; DSM-III-R; 89% of sample took stimulant medication</td>
<td>Descriptive statistics, graphs</td>
<td>Children with ADHD performed below the 25th percentile compared to the norms of a VO$_2$max test (Leger et al., 1984), shuttle run test (CAHPER, 1980), and sit-up test (Fitness Canada, 1985). Flexibility and push-ups scores (Fitness Canada, 1985) were below the 40th percentile of the respective norms. Excess body fat was found (75th percentile) on a skinfold test (Fitness Canada, 1985).</td>
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<td>Trocki-Ables, French, &amp; O’Connor (2001)</td>
<td>Described the effects of 3 different types of reinforcement on the amount of time spent to complete a 1 mile/1.6 km walk/run test</td>
<td>5 boys; ADHD; 8-10 years; diagnostic framework not reported; medications were not reported</td>
<td>Single subject methodology descriptive, graphs</td>
<td>Visual inspection of the individual graphs (Time in seconds x Trials) revealed that boys with ADHD performed the walk/run test in less time when provided both tokens and verbal praise rather than when provided just tokens or verbal praise alone.</td>
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*Note. ADHD = attention-deficit/hyperactivity disorder, ND = no disability, * = (p < heart rate, mean blood pressure).
and a sit-up test (Fitness Canada, 1985). Flexibility and push-ups were also performed below the 40th percentile (Fitness Canada, 1985).

These three studies (Ballard, 1977; Boileau et al., 1977; Harvey & Reid, 1997) provide an initial picture of health-related fitness. The findings indicate that children with ADHD are at risk to develop problems associated with health-related physical fitness.

Trocki-Ables, French, and O’Connor (2001) described the effects of different reinforcers on the performance of the 1 mile/1.6 km walk/run test (Cooper Institute, 1992) for 5 boys with ADHD. Each boy was asked to complete the walk/run test as quickly as possible on each of 29 trials. One trial was held each day during a 6-week data collection period. There were three data collection phases. The first phase was three initial trials that served as baseline. The intervention phase consisted of 24 trials where reinforcers were randomly provided with either a token (primary), verbal praise (secondary), or in combination when the individual lap time fell below the baseline average. The last phase of the data collection period was a generalization period where two trials were conducted without reinforcement. Trocki-Ables et al. concluded that boys with ADHD perform the walk/run test in less time when provided with combined primary and secondary reinforcers rather than primary or secondary reinforcers alone.

Clearly, there is a lack of physical fitness research about children with ADHD. Existing research should be considered as preliminary because the studies have relatively small sample sizes with wide age range variability. Yet interesting questions do arise from careful observation of the existing findings. For example, the effects of stimulant medication on respiratory rates need to be examined as methylphenidate produced significant increases in respiratory rate during rest and significant decreases in respiratory rate during exercise (Ballard, 1977; Boileau et al., 1977). Furthermore, no researcher has examined the effects of stimulant medication on HR during high intensity exercise. Also, we should use longitudinal studies to examine relationships between persons with ADHD, health-related physical fitness, and exercise. For example, are children with ADHD “at risk” for developing cardiovascular heart disease? Are the physical fitness findings reflective of the current sedentary lifestyles of North American children?

Studies about the health-related fitness of adolescents and adults with ADHD are also needed (Hartmann, 1993). Research questions about adult ADHD may be found in a review about the properties of stimulant medications, with many ethical implications for adapted physical activity (Hickey & Fricker, 1999). For example, stimulant medications are banned in many sports competitions. Hickey and Fricker questioned whether guidelines should be created to accept the performance of athletes who have ADHD and have stopped taking medication at least 24 hr prior to competition.

Conclusions

Our first conclusion deals with the enormity of the ADHD literature. There are many exciting avenues of research and practice in ADHD and adapted physical activity, but it is difficult to achieve a thorough conceptual grasp of the disorder. Adapted physical activity will be influenced by definition, diagnosis, etiology, nomenclature, classification, and treatment in ADHD.
We conclude that the movement skills of children with ADHD are at risk when compared to chronological age-matched peers, although as noted throughout the paper, there is much to be learned. The reviewed studies present converging evidence that supports the description of children with ADHD as having problems of movement performance from the vantage point of parents, teachers, and researchers. This performance is not a function of overactivity that masks valid assessment, given deficits noted in both quantitative (Beyer, 1999; Harvey & Reid, 1997; Miyahara et al., 1995, 2001; Piek et al., 1999) and qualitative (Harvey & Reid, 1997) performance. Our conclusion is based on aggregate data. We recognize that some individuals with ADHD may excel in movement skills. Moreover, there is growing evidence that ADHD and DCD might be comorbid conditions. The aggregate is therefore influenced by those who also have DCD. Future research should describe movement skills in ADHD when those who warrant the specific designation of DCD are eliminated from the participant pool. Would ADHD still be associated with inferior movement skill performance?

We conclude tentatively that children with ADHD are at risk for poor levels of physical fitness in comparison to their chronological age-matched peers. We are more careful with this conclusion than with movement skills because the literature is not as complete about health-related fitness. The relationship between the physical activity levels of children with ADHD and physical fitness needs to be explored. Comprehensive fitness assessment batteries with large sample sizes are strongly recommended to observe if children with ADHD possess different physiological markers than their age- and gender-matched peers without disabilities. Clearly, the interaction between physiological responses and medication should also be addressed in the exercise context.

It will be crucial to develop collaborative research projects with professionals in psychology, psychiatry, or special education. Detailed physical activity information may be invaluable for clinical intervention. Increased sample size, diagnostic reliability, and opportunities to explore movement issues of children with ADHD, DCD, or DAMP may also be realized.

Much of the existing movement behavior research is atheoretical. Future physical activity researchers should use theoretical models to guide their research. For example, Barkley (1997) has developed a comprehensive theoretical framework to explain the underlying mechanisms of ADHD. Movement behavior is an element included in this paradigm, which could be tested by physical activity researchers. The activity-deficit hypothesis (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996) could also be an explanation for the movement skill difficulties of children with ADHD, where poor movement skills may lead to a diminution of affect, or vice versa, resulting in reduced social interaction, decreased levels of physical activity, and diminished physical fitness and health.

It is hoped that this article will benefit adapted physical activity practitioners and researchers. There remain many unexplored physical activity questions to stimulate further research. In turn, the findings may prove beneficial for the health and welfare of people with ADHD and their families.

References


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Authors’ Notes

1In fact, the published literature is so large that there has been at least one meta-analysis of meta-analyses performed (Swanson et al., 1993).

2Identifiers include motor processes (P), movement performance - retrospective views (MR), movement performance - large descriptive studies: movement skills (D1) and physical fitness (D2), movement performance - skill performance (MS), movement performance - physical fitness (MF).

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