Novel physiotherapies

Archer and Garcia, J Nov Physiother 2014, 4:3
http://dx.doi.org/10.4172/2165-7025.1000208

Review Open Access

Physical Exercise Improves Cognition and Health in ADHD

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Rec date: Mar 05, 2014, **Acc date:** Apr 16, 2014, **Pub date:** Apr 21, 2014

Abstract

Attention-Deficit Hyperactive Disorder (ADHD) disrupts normal functioning and health parameters in children and adults with the additional burden of continuing on into adulthood thereby implying marked disadvantages over the individual's life-span. In this paper we review interventions that incorporate physical exercise programs, independent of specific type of activity or the proportions or endurance/resistence ingredients. These interventions have been found invariably to improve and alleviate symptom profiles, sometimes replacing the traditional treatments. In many cases, the presence of accompanying behavioral disruptions may be alleviated through exercise regimes.

Keywords: ADHD; Exercise; Symptoms; Children; Adults; Intervention

Physical exercise and health

Physical exercise impacts upon several domains of psychological and physical structure and function, including cognition, emotion, brain biomarkers and structural integrity that maintain function and plasticity. Evidence from several perspectives has reinforced the notion that exercise intervention ought to be integrated with conventional therapies for the improvement of brain function and resistance to neurodegenerative and neuropsychiatric disorders in addition to offering a complementary non-pharmacological, noninvasive alternative [1,2]. Variety in physical exercises provides necessary strengthening and stretching of muscles combined with relaxation with each selected program 'taylor-made' to comply with individual profiles. For instance, recent research has found relations among specific personality and heart rate variability; thus, supporting the strong relations among personality, heart rate variability, and health [3]. In the laboratory, studies on healthy older rodents have demonstrated that regular aerobic exercise promotes plasticity-related changes in the brain and the central nervous system (CNS) that include synaptogenesis, neuronal arborization, enhanced glucose utilization, angiogenesis and neurogenesis [4]. Life-long spontaneous exercise was found not to prolong life-span but rather improved health-span in mice [5]. Kirk-Sanchez and Gough [6] have argued that physical exercise programs defined by special parameters, that is, structured, individualized, higher intensity, longer duration, robust against mishap and with multiple components provide new horizons for the preservation cognitive performance, mediated through several domains, in older adults and the aged.

The necessity for physical activity/exercise to ensure normal, healthy development of structure and function in children and adolescents remains inestimable, as evidenced from global public health physical activity guidelines [7-9], not least due to prevailing concerns regarding body mass in the young [10]. Several established child-youth resistance training programs with proper design and supervision describe (i) Moderate-intensity aerobic activity, (ii) Vigorous-intensity aerobic activity, (iii) Muscle-strengthening activity, and (iv) Bone-strengthening activity that ensure safety and prospects for compliance. These programs have been found to enhance muscular strength and power, improve the cardiovascular risk profile, enhance motor skill and performance, to provide a superior resistance to sports injuries, improve psychological well-being and self-fulfillment, and optimize cognitive functioning [11,12]. Exercise promotes healthy brain condition by reducing inflammation, suppressing oxidative stress and stabilizing calcium homeostasis [13]. In children and adolescents, physical activity is linked with improved self-esteem and self-concept, in addition to reduced anxiety and depression [14]. Mood alterations are generally accompanied by benefits in cognition and academic performance: both acute and chronic exercise promoted executive functioning [15,16]. Probably the major relevance of the exercise habit and life-style that is established during childhood is that it appears to persist into adulthood and beyond [17]. The challenge of physical activity upon neurobiological processes engages adaptive cellular stress-response signaling pathways in neurons by involving neurotrophic factors, protein chaperones (these prevent both newly synthesised polypeptide chains and assembled subunits from aggregating into nonfunctional structures), DNA-repair proteins, autophagy and mitochondrial biogenesis [18].

Exercise in Attention-Deficit Hyperactive Disorder (ADHD)

Much evidence suggests that ADHD presents the most common neurobehavioral childhood disorder accompanied by pervasive and debilitating symptoms that include primarily lack of attention, hyperactivity and impulsiveness, with or without conduct disorders and aggressiveness [19]. Exercise has been shown to affect similar dopaminergic and noradrenergic pathways that stimulant drug medications (e.g., methylphenidate) target and is a stressor also [20], which elicits measurable physiological changes influencing its interventional status. Children, adolescents and adults presenting ADHD symptoms show deficits in behavioral inhibition, executive

functioning, goal-oriented activity and emotional regulation [21-25]. It appears that physical activity interventions for children should be designed to meet multiple objectives; e.g., optimize physical fitness, promote health-related behaviors that offset obesity, and facilitate mental development [26]. Acute physical exercise improves all these expressions of problem [27-30] and provides problem-management through physiological mechanisms [31-33]. One half-hour of aerobic treadmill running, compared with stretching in the control condition, induced immediate improvements in response speed, vigilance and stimulus discrimination on a go/no go task, lower response speed variability and lower impulsivity in 25 boys, aged between 7 and 15 years, presenting ADHD [34]. Furthermore, participation in a physical activity program improved muscular capacity, motor skills, behavior reports by parents and teachers, and level of information processing in ADHD children [35,36]. Hung et al. [37] studied the relationship between motor ability and response inhibition using behavioral and electrophysiological indices in 32 ADHD children by applying concurrent measurements of the Basic Motor Ability Test-Revised (BMAT) as well as the Go/No-Go task and event-related potential (ERP). They observed that the BMAT scores were associated positively with the behavioral and ERP measures, such that the BMAT average score was associated with a faster reaction time and higher accuracy, whereas higher BMAT subset scores predicted a shorter P3 latency in the Go condition. The authors concluded that the ability in the motor domain influences benefit the cognitive performance of ADHD children at different levels.

ADHD children often present cognitive impairments, particularly regarding executive function [38-40]. Despite the prevalence of pharmacological (CNS-stimulant) and behavior-therapeutic interventions, voluntary physical exercise affects positively brain plasticity through reversing neurodegenerative and enhancing neuroadaptive, neuroreparative and neuroprotective processes [41-43]. There appear to be multiple associations between physical activity/exercise and a variety of markers for physical and psychological health in adolescents and young adults [44-46]. Within the context of ADHD interventions, it appears that the associations between physical exercise, executive functioning and the ADHD symptom-profile ought to offer relevant and necessary implications for developmental trajectories [47]. It has been observed that acute resistance exercise facilitates general cognition but has a more beneficial effect on cognition that involves executive control [28,48]. In consensus with animal studies [49,50] exercise interventions are associated with enhancement of cognitive function, particularly executive function in both old and young [51-53] and frontal lobe structure and function [54,55]. For example, Berchicci et al. [56] have shown that physical exercise speeded up the responses of older adults thereby revealing that even in middle-aged people, moderate-to-high levels of physical exercise benefits the planning/execution of a response and the executive functions mediated by the prefrontal cortex, counteracting the neural over-activity observed often in the elderly adults.

It has become increasingly evident that childhood ADHD continues, in a large proportion of afflicted individuals, into adulthood with the accompanying risk of co-morbidity [57-59]. These individuals suffer from several psychological disadvantages compared to healthy individuals: for example, in a study of internalizing and externalizing behavior by 910 ADHD adults, it was observed that there were significantly higher scores of the anxiety- and depression-related personality traits Neuroticism and Harm Avoidance [60]. In a study of adults diagnosed with ADHD, Abramovitch et al. [61] have reported that ADHD adults who had pursued a program of frequent aerobic physical activity/exercise experienced significantly less behavioral impulsivity and fewer worrisome and intrusive thoughts thereby concluding that there was a link between exercise frequency and increased impulse control but reduced thought disturbances. Applying adult animal laboratory models of ADHD (e.g. spontaneously hypertensive rats), it has been observed that physical exercise offers an adjunctive or replacement therapy in ADHD [49,62]. Kim et al. [62] showed that physical exercise in the form of Treadmill running in combination with methylphenidate alleviated the symptomatic hyperactivity and the spatial learning memory deficits in spontaneously hypertensive (ADHD) rats. Expressions of tyrosine hydroxylase, essential for dopamine synthesis and brain-derived neurotrophic factor are reduced in these rats. They observed that expressions of both tyrosine hydroxylase and brain-derived neurotrophic factor were elevated in the ADHD rats following exercise and methylphenidate. Szuromi et al. [63] have shown that symptom frequency and number, particularly impulsiveness, exert a marked impact upon functional integrity in ADHD adults. Additionally, complaints and disorders related to the 'self-concept' ought to be assessed. Furthermore, P300 event-related potential component, an endophenotype for ADHD, was observed to be reduced in adult ADHD patients with reference to a neurodevelopmental notion of disorder [64]. As indicated above [61], physical exercise proved useful for reducing impulsiveness in ADHD adults. Thus, the positive implications and psychosocial benefits of exercise in this context have been documented [65]. On a note of caution, Goodwin et al. [66] have found that compulsive exercise was associated significantly with emotion regulation, after taking into account disordered eating attitudes. Among adolescent boys, compulsive exercise was associated with internal functional, internal dysfunctional and external functional emotion regulation strategies. Among adolescent girls, internal functional and internal dysfunctional emotion regulation strategies predicted compulsive exercise. Compulsive exercise, or "exercise bulimia", presents a strong and compelling desire to exercise in an effort aimed at burning the **calories** of **food energy** and **fat reserves** to an excessive level that affects negatively the **health** of these individual. This condition, like ADHD, is characterized by high levels of impulsive behavior.

In conclusion, physical exercise has been observed consistently to promote a plethora of health benefits over several domains of structure and function, including developmental and adult brain disorders, traumatic brain injury, neuroimmune functioning and affective disorders. ADHD, as a wasteful and debilitating condition, affects not only the hyperactivity, loss of attention and impulsiveness domains but also variety affective states, such as compulsive states, that contribute to the general malaise. A variety of physical exercise interventions, both endurance- and resistance-promoting, have pertained to the utility that may both alleviate, and even abolish, symptom profiles; in certain cases, even replacing traditional pharmacologic treatment. As an intervention with preventive properties, it is cheap, noninvasive, non-pharmacological and permanently available. Essentially, ADHD disempowers individuals, some permanently. The development of resilience, cognitive capacity and emotional control through exercise schedules [67] empowers these individuals to a new level of developmental trajectory.

Acknowledgements

The development of this article was supported by The Bliwa Stiftelsen and AFA Insurance.

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