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An Innovative Approach towards Selecting Aerobic and Coordinative Exercises in Clinical Practice for Children and Young People with ADHD

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Abstract

A growing body of studies and systematic reviews show evidence of the beneficial effects of physical exercise on core symptoms of ADHD. Furthermore, studies indicate that physical exercise as an adjuvant can enhance the effects of medication in the treatment of ADHD. Aerobic and coordinative exercises improve executive functioning through their effect on neurocognitive domains that are implicated in ADHD. It is postulated that through their specific modus operandi, aerobic exercise, by raising cortical arousal levels, improves impaired alerting functions whereas coordinative exercises improve the regulation of inhibitory control through the involvement of a higher variety of frontal-dependent cognitive processes. The increasing use of routine neurocognitive testing with continuous performance tests (CPT), such as the QbTest, at clinical assessments for ADHD allows for an innovative approach to identify the assessment impairments in alerting function and inhibition control that are related to ADHD and accordingly choose aerobic or coordinative physical exercise in a more targeted fashion.

Keywords

ADHD, Physical Exercise, Aerobic Exercise, Coordinative Exercise, Continuous Performance Test (CPT), QbTest, Medication, Treatment

1. Introduction

The beneficial effects of physical exercise on an individual's health and quality of life are well known [1].

In 2019, The UK Chief Medical Officer published physical activity guidelines based on compelling evidence supporting the health benefits of regular physical activity. It states that in children and young people, regular physical activity is associated with improved learning and attainment, better mental health and cardiovascular fitness. The guideline recommends that children and young people engage in moderate-to-vigorous intensity physical activity for an average of at least 60 minutes per day across the week [2].

Furthermore, a growing body of literature highlights the beneficial effects of exercise on core symptoms of attention deficit hyperactivity disorder (ADHD) with regular moderate to maximum intensity aerobic exercise providing the most consistent results [3]-[5].

At a neurophysiological level, as shown in animal studies, exercise induces increased central arousal and elevates the release of frontostriatal neurotransmitters, such as dopamine, epinephrine, norepinephrine and serotonin [6].

In a group of children with ADHD, Tantillo *et al.* (2002) observed acute exercise-related changes in spontaneous eye blink rate and acoustic eye-blink startle response, which are considered non-invasive indicators of dopaminergic activity as they are sensitive to dopamine agonists [7].

Interestingly, the neurophysiological changes found to be induced by exercise impact on areas that overlap with the neuropathological mechanisms implicated in ADHD [8]. Hence, it appears that the mechanism through which exercise induces its effects on alleviating core ADHD symptoms is akin to enhanced dopaminergic neurotransmission and would suggest some parallels with the pharmacological effect of ADHD medications.

Thus, with its mode of action on the same cortical structures and neurotransmitters in the brain, two randomized controlled trials investigating the effects of exercise in addition to pharmacological treatment with stimulant medication demonstrated that exercise enhanced the effects of medication and led to improved task performances compared to a control group with educational sessions and medication [9] [10]. Additionally, a study by Feng *et al.* (2021), showed that a combination of balance training and stimulant medication led to a decrease in stimulant dosage at the end of the trial while the dose of the control group (medication only) remained at a steady level. At the same time balance training and medication significantly increased improvement in the symptoms and behaviour associated with inattention compared to the control group whose treatment consisted of only methylphenidate [11].

These findings bear important clinical relevance considering that children on continued medication treatment for 6 - 8 years may reach a 41% increase in their average total daily dose of stimulant medication as shown in the MTA prospective follow-up study [12]. Adding regular exercise to the treatment with stimulant medication may prevent the need for frequent dose increases and as a result reduce the risk of exposure to drug-related side-effects.

Hence, physical exercise offers a therapeutic effect in children and young people with ADHD, both on its own or in combination with pharmacological treatment.

2. Aerobic & Coordinative Exercises

2.1. Aerobic Exercise

The immediate effects of acute exercise can be measured as improvements in neurocognitive functions of certain neurocognitive domains that are known to give rise to symptoms of ADHD.

The majority of studies examined the effects of moderate-intensity aerobic exercise and found post-exercise improvements in neurocognitive tests such as Flanker task, Stroop task and Go/No Task.

Most commonly, a reduction in reaction time and increased P 300 amplitudes in EEG readings point towards a mechanism whereby aerobic exercise increases cortical arousal levels in brain areas associated with executive functions [6]. This finding is of particular importance for children and young people whose ADHD is predominantly related to impairment in alerting and arousal functions associated with a state of hypo-arousal in prefrontal cortical areas [13] [14].

2.2. Coordinative Exercise

The volume of studies examining the effects of coordinative exercise on ADHD symptoms is in contrast to aerobic exercise still small and a matter of growing interest [15].

Coordinative exercises mobilise prefrontal cortex activity during the execution of a motor task and its practice is considered to improve cognitive functions, in particular inhibitory control [16]. These improvements have been replicated in children and young people with ADHD who demonstrated better-sustained attention and inhibitory control following coordinative exercises [11] [15] [17].

Furthermore, some research data suggests that in healthy children and adolescents, coordinative exercises provide higher benefits on cognitive function compared to aerobic exercise (Amatriain-Fernández *et al.* 2021), possibly because coordinative exercises require a higher variety of frontal-dependent cognitive processes [18] [19].

Studies with coordinative exercises used a combination of dynamic and static balance exercises and authors concluded that both were effective for children and young people with ADHD. Prior to commencing the trial, participants were tested for their coordinative ability and exercises adjusted to the individual's coordinative skills [20] [21]. Feng *et al.* noted that the goal of the balanced treatment was to reach a point where patients had the ability to maintain a balanced posture even when experiencing sensory conflict [11].

2.3. Aerobic vs. Coordinative Exercise

There is one study by Ludyga *et al.* (2017) which provides a comparison between the effects of aerobic and coordinative exercises in children and young people with ADHD showing greater improvements for aerobic exercise on reaction time and thus level of cortical arousal [20]. In contrast, a study by Chang *et al.* (2014) proposed that the coordinative component of a combined aerobic/coordinative exercise program led to beneficial effects in inhibition control since reaction time was not significantly altered [15].

Overall, results suggest that differences in effect are likely due to their distinctive characteristics of modus operandi by which aerobic and coordinative exercises exert their beneficial effect on executive functions.

For that reason, some authors are proposing to conduct more targeted and selective exercise programs for future research [1]. Along those lines, Ziereis and Jansen (2015) selected two exercise groups comparing exercises with specific abilities, such as ball handling, balance and manual dexterity with non-specific exercises such as swimming, running, climbing and sports games. Both groups showed beneficial effects on executive functions compared to a non-active control group [22].

2.4. Receptiveness to Exercise and Engagement

In order to derive the benefits of both aerobic or coordinative exercise the intensity, duration and frequency of the exercise programme is crucial for developing a therapeutic effect. A meta-analysis by Xiao *et al.* (2021) found that overall executive function was significantly moderated by intervention intensity and exercise sessions of intervention but not by exercise type, suggesting that moderate intensity exercise conducted once or twice weekly over 6 - 12 weeks accounted for moderate-to-large training effects [4].

Research also highlights the influence of psychosocial effects such as increased patient care and social group activity on engagement and outcome [6]. These aspects are important to consider for the successful implementation of a therapeutic exercise programme for children and adolescents with ADHD.

3. Integrating Findings for Daily Clinical Practice

Do the results provide clinical practitioners with the tools in their toolbox to suggest a selection of physical exercises for specific difficulties in children and young people with ADHD?

3.1. Alerting Functions & Inhibitory Control

Clinical research has focused on the effects of physical exercise on the two aforementioned neurocognitive domains of alerting functions and inhibitory control. These two domains are well known to give rise to symptoms of ADHD as supported by an extensive amount of research literature [23]-[28].

In the first instance, clinicians would have to identify children and young people with ADHD who demonstrate difficulties in their alerting functions or inhibitory control. It would then be possible to recommend and specify the benefits of aerobic exercise on alerting functions and the benefits of coordinative exercise on inhibitory control.

3.2. History Taking

"Alerting" is the ability to prepare for what is about to happen when a warning is received, or to be ready to respond without warning [23]. In taking a history of behaviour, the following features should be present: Children and young people with an alerting deficit tend to react slowly and their responses are inaccurate when time is of the essence. They find it difficult to redirect their wandering mind to the task at hand. A state of low alertness makes it difficult for the child to control or mobilise their responses as shown in behaviours such as making careless mistakes and procrastinating behaviour.

In contrast, children and young people who have marked problems with inhibitory control, demonstrate an inability to suppress irrelevant behaviours as the context changes [23]. The predominant features in the assessment arise as hasty responses leading to mistakes or interruptions during an activity where the child should be trying to keep on task in an ongoing way.

3.3. Questionnaires

Both, impairment in alerting functions and impairment in inhibitory control are known to bring about behaviours that expand over all three core symptom domains of ADHD (hyperactivity, inattention, impulsivity). As a result, both impairments are known to present as ADHD-combined types in commonly used clinical questionnaires (Conners 3; SNAP IV) rather than differentiating themselves from one another [29] [30]. Subsequently, clinical questionnaires do not lend themselves as an aid in identifying these two neurocognitive domains.

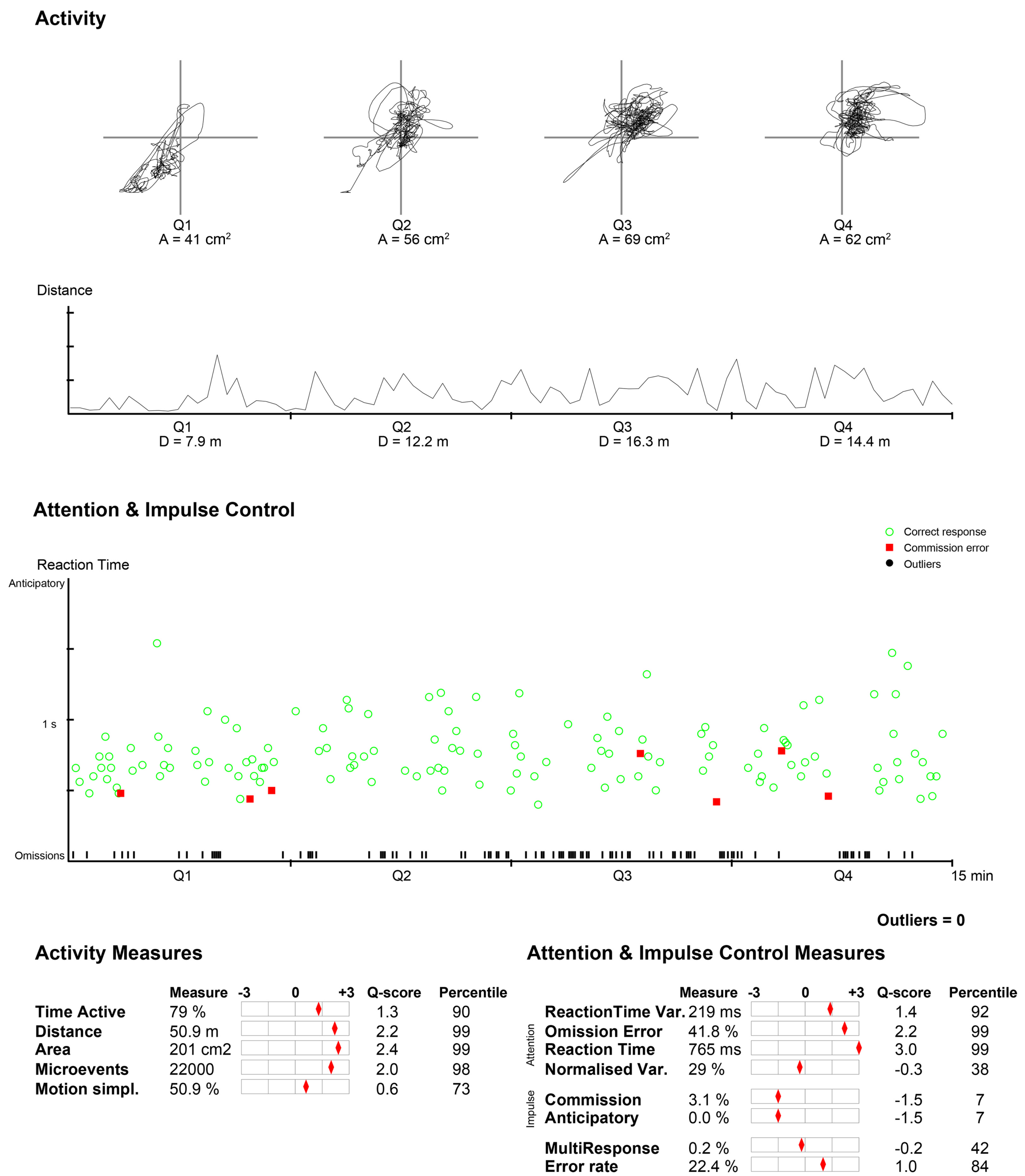
3.4. Adding Neurocognitive Testing to the Clinical Assessment

A pivotal addition in aid of the assessment of alerting functions and inhibitory control comes with the wider inclusion of neurocognitive testing such as the Go/No-go Test or continuous performance test (CPT) for the assessment of ADHD in clinical practice [31]-[33]. These tests offer clinicians a direct measurement of neurocognitive domains in a clinical setting.

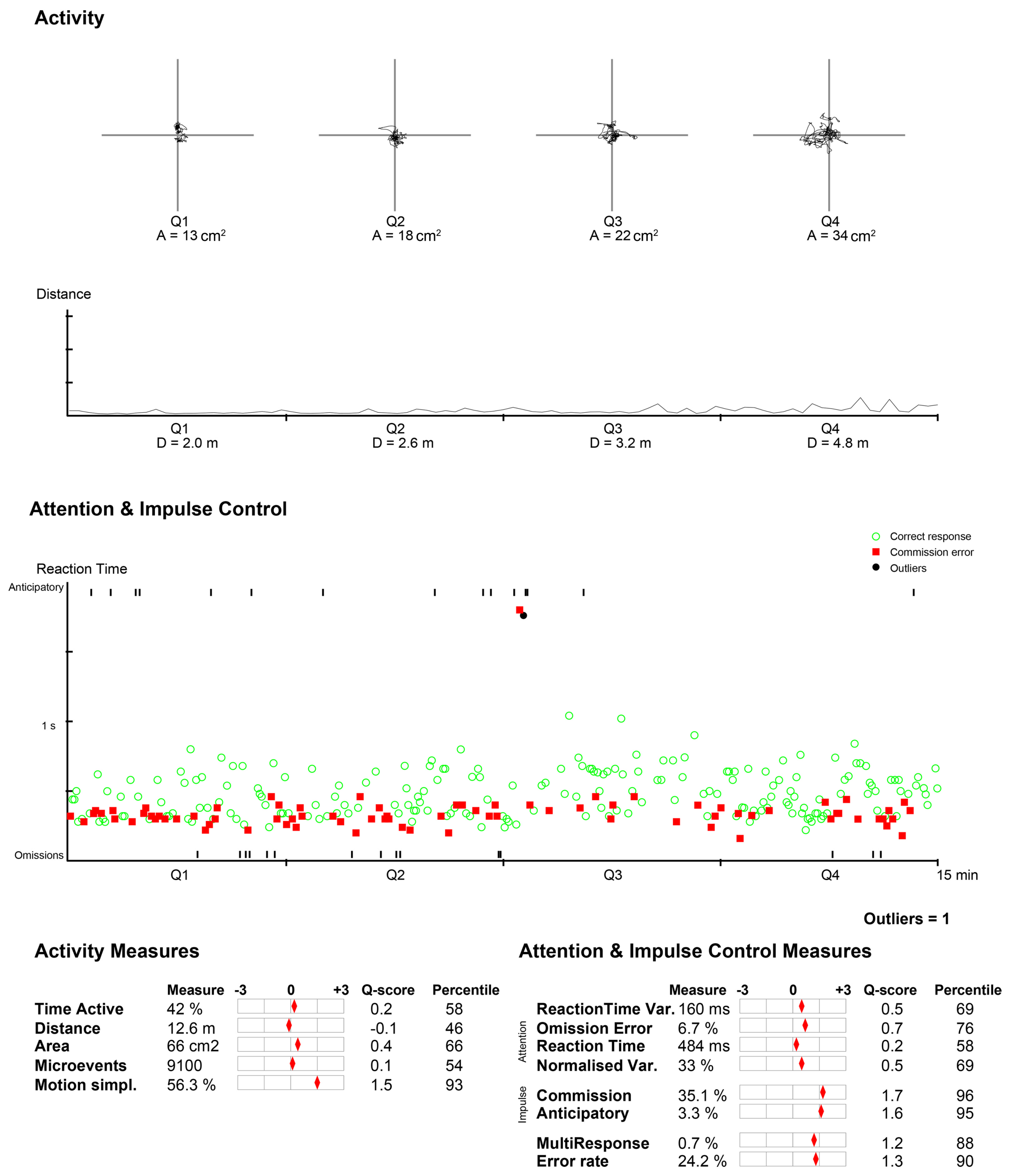
As an example, one of the commercially available tests, the QbTest, lays out a visual graph, which captures a distinct pattern/profile of performance that can clearly differentiate between impairment in alerting functions (**Figure 1(a)**) and impairment in response inhibition (**Figure 1(b)**) [34] [35].

Cases demonstrating weaknesses in arousal and alerting functions display in their individual parameters a slow reaction time, elevated variable response time and increased omission errors (failing to respond to the target stimulus), resulting in a graph profile marked by slow, scattered and loose target responses (green circles; **Figure 1(a)**).

Cases with impairment in response inhibition and inhibitory control manifest themselves by increased commission errors (failing to suppress response to non-target) with normal reaction time and reaction time variation. The graph profile characteristically shows a red carpet effect reflecting hasty commission errors (red squares; Figure 1(b)) within a dense responding pattern.



(a)



(b)

Figure 1. (a) & (b): The vigilance/alerting function profile (a) shows a typical scattering of correct green responses with slow and inconsistent speed resulting in slow reaction time and increased reaction time variation. The increased number of little bars on the x-axis represents omission errors. Activity is on average raised. In the response inhibition profile (b), fast incorrect responses or commission errors (red squares) underline the carpet effect. Activity is on average normal (from Vogt. C. Clinical Conundrums When Integrating the QbTest into a Standard ADHD Assessment of Children and Young People. Neuropediatrics 2021 Jun; 52(3): 155-162. doi: 10.1055/s-0040-1722674. Epub2021 Jan 14.)

3.5. Combining Information

Thus, as part of a comprehensive assessment that includes neurocognitive testing, it is possible to match behaviours that are suggestive of difficulties in e.g. alerting functions or inhibitory control with their corresponding scores and profiles from neurocognitive testing and thus achieving the objective of identifying children and young people with ADHD that would benefit more from aerobic exercises or coordinative exercises (Table 1).

Table 1. Overview of impaired alerting function and impaired inhibitory control with their clinical behavioural features and associated findings in neurocognitive testing. The exercise that has a primary effect on the specific neurocognitive domain is included.

ADHD		
Neurocognitive domain	Impaired Alerting Function	Impaired inhibitory control
DSM-5 diagnostic criteria	ADHD-combined type	ADHD-combined type
Neuropsychological impairment	Delayed ability to prepare for what is about to happen and to be ready to respond	Difficulty in response inhibition when trying to suppress a behaviour when the context changes
Typical behavioural features	- Careless mistakes or inaccurate responses when time is of the essence - Procrastination - Excessive mind wandering	- Hasty mistakes or hurried responses in situations that call for waiting, e.g. blurting out a reply before listening to the whole sentence
Neurocognitive test Continuous performance test/QbTest	- Slow reaction time - Increased reaction time variation - High rate of omission errors - Low rate of commission errors	- Normal reaction time - Normal reaction time variation - High rate of commission errors - Low rate of omission errors
The primary effect on the neurocognitive domain	aerobic exercises	coordinative exercises

4. Heterogeneity

There is of course a wider spectrum of functional impairments associated with ADHD than alerting functions and inhibitory control alone and which clinicians routinely consider when assessing children and young people with ADHD [36]-[38]. These too, should respond to the general effects of physical exercise. However further studies are required to help ascertain potential differences in efficacy when using specific types of physical exercise [39] [40].

Table 2. Mechanism and examples of aerobic and coordinative exercises plus a guide on how to determine moderate intensity activity and the recommended duration of one exercise session.

Physical Exercise	Aerobic exercise	Coordinative exercise	Moderate Intensity
Mechanism	Activation of the cardiovascular system to generate energy and meet energy demands via aerobic metabolism	Activation of motor units of multiple muscles with simultaneous inhibition of all other muscles in order to carry out a desired activity	Moderate and vigorous activity can be differentiated by the "talk test": being able to talk but not sing indicates moderate intensity activity, while having difficulty talking without pausing is a sign of vigorous activity.
Examples	- Running, swimming, cycling - Age appropriate core body strengthening exercises	- Balancing on one leg - Exercises demanding object control skills (catching and throwing a ball) - Bilateral coordination of lower and upper extremities (stepping through colored rings in a predefined order)	
Duration (minimum)	30 minutes	30 minutes	

5. Conclusions

Both aerobic and coordinative exercises have general benefits on executive functioning in ADHD.

Acute benefits emerge with at least 30 minutes of moderate-intensity exercise.

Moderate-intensity exercise once/twice weekly over 6 - 12 weeks accounts for moderate-large training effects.

The psychosocial effect of group exercise programmes aids in engagement in physical exercise.

Differences in effect are likely due to differences in mode of action.

Aerobic exercise raises cortical arousal levels and coordinative exercises involve a higher variety of frontal-dependent cognitive inhibitory processes.

Combining clinical assessment with neurocognitive testing can identify children and young with ADHD whose symptoms may be predominantly associated with alerting functions or inhibitory control (Table 1).

The effects of physical exercise may be enhanced when matching certain types of exercise with certain types of neurocognitive difficulties in ADHD (Table 1 and Table 2).

Physical exercise enhances the effect of stimulant medication. A combination of regular exercise and treatment with stimulant medication leads to a reduction in medication dosages required to treat symptoms of ADHD compared to treatment with stimulant medication alone.

Future research is required to confirm enhanced effects of targeted exercise.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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