## Physical Activity for ADHD

A Guided Review of the Literature and Evidence



## Learning Objectives

- Describe the efficacy of physical activity interventions for the treatment of ADHD-related symptoms.
- Identify what kinds of exercise are associated with improvements in ADHD symptoms.
- Identify dose response (e.g., frequency, intensity) of exercise associated with improvements in ADHD symptoms.
- Make recommendations for the inclusion of physical activity for clients with ADHD symptoms.

## **Conflict of Interest Statement**

- The Center for Movement-based Psychotherapy is committed to the mission of sharing evidence-based practices for the inclusion of movement, physical activity and exercise as modalities for the prevention and treatment of mental health symptoms and disorder.
- The Center for Movement-based Psychotherapy has received no commercial or third-party support for or in the making of this lecture or the information there-in.
- The Center for Movement-based Psychotherapy and the instructor of this lecture have no known conflicts of interest.

## **Evaluating Intervention Efficacy**

#### Prevention:

• Is there evidence to suggest that physical activity/exercise can help **prevent** ADHD symptoms?

#### Therapeutic:

• Is there evidence to suggest that physical activity/exercise can help **alleviate**/decrease ADHD symptoms?

## ADHD in the DSM-V: Inattention

Six (or more) of the following symptoms have persisted for at least 6 months; the individual often:

- Fails to give close attention to details or makes careless mistakes in schoolwork, at work, or during other activities
- Difficulty sustaining attention in tasks of play activities
- Does not seem to listen when spoken to directly
- Does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace

- Has difficulty organizing tasks and activities
- Avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort
- Loses things necessary for tasks or activities
- Easily distracted by extraneous stimuli
- Forgetful in daily activities

### ADHD in the DSM-V: Hyperactivity/Impulsivity

Six (or more) of the following symptoms have persisted for at least 6 months; the individual often:

- Fidgets with or taps hands or feet or squirms in seat
- Leaves seat in situations when remaining seated in expected
- Runs about or climbs in situations where it is inappropriate
- Unable to play or take part in leisure activities quietly

- On the go" acting as if "driven by a motor"
- Talks excessively
- Often blurts out an answer before a question has been completed
- Often has trouble waiting for his/her turn
- Often interrupts or intrudes on others

### **ADHD in the DSM-V**

- Symptoms were present before the age of 12.
- Symptoms present in two or more settings.

Clear evidence that the symptoms interfere with, or reduce the quality of, social, school or work functioning.

- Combined presentation
- Predominantly inattentive
- Predominantly hyperactive-impulsive

## Physical Activity for ADHD

Part 1: Intervention and Therapeutics



## Managing Childhood and Adolescent ADHD with Exercise

#### 2017 Systematic Review

- 30 Studies (n = 1,287)
  - Only six of the studies were randomized control trials

#### Key Findings:

- Cognitive, behavioral and physical symptoms of ADHD were alleviated with physical activity interventions.
- The largest intervention effects were reported for mixed exercise programs.

## Managing Childhood and Adolescent ADHD with Exercise

#### Highlights:

- Physical activity (PA) (in particular moderate-to-vigorous aerobic exercise) is a beneficial and well-tolerated intervention for children and adolescents with ADHD.
- No adverse effects were noted from the studies included; suggesting that exercise is well-tolerated with few (if any) contraindications.
- The majority of participants in the review were male (this is a common theme among ADHD research).

## **Cognitive Benefits of Acute Physical Exercise in Children with ADHD**

#### 2017 Systematic Review

• 3 studies (n = 96)

#### **Key Finding:**

- 30 min of exercise reportedly improved the executive functions of children with ADHD.
- Due to the small number of articles selected, further studies are needed to confirm these benefits.

## **Cognitive Benefits of Acute Physical Exercise in Children with ADHD**

#### Highlights:

- Each study used some type of aerobic exercise (e.g., Bicycle, Treadmill)
- Outcomes include: Impulsivity, vigilance, reaction time, inhibitory control, selective attention, problem solving
- One study compared individuals with ADHD to those without ADHD but not control group
- One study used stretching as a control, another used "watching a video about running and exercise" as a control

## Physical Activity on Cognition and Behaviour in Young People with ADHD

#### 2018 Systematic Review

- 16 Articles (7 acute intervention studies; 9 chronic intervention studies; n = 728)
  - "Young people" includes sample 8 to 18 years old.

#### Key Findings:

- Between 20 and 30 minutes of moderate-vigorous intensity showed acute effects on improvement of cognition in young people.
- PA between 5 to 20 weeks chronic effects that improve cognition and behavior in young people with ADHD.

## Physical Activity on Cognition and Behaviour in Young People with ADHD

#### Highlights:

- Cognitive improvements in processing speed, working memory, planning and problem solving.
- Behavioral symptoms are improved but results are more mixed.

## Effects of Physical Activity on Cognitive and Academic Performance

#### 2019 Systematic Review

- 58 Intervention Studies (11 High quality, 29 Moderate quality, 18 Weak quality
  - The 11 studies deemed "High quality" were reviewed.

#### Key Findings:

- 48% showed a significant benefit for cognitive performance and
- 60% showed a significant benefit for physical activity and for academic performance.

## Effects of Physical Activity on Cognitive and Academic Performance

#### Highlights:

- Evidence from "high quality studies" is mixed/inconclusive.
- Strongest evidence for academic performance outcomes was for math performance.
- Need for more high-quality intervention studies to establish potential causal relationships.

## Impact of Physical Exercise on Children with ADHD

#### 2019 Systematic Review and Meta-Analysis

• 14 total studies including 8 studies were randomized control trials, 6 were observational studies (n = 574)

#### Key Findings:

- Anxiety and depression were significantly improved in children with ADHD.
- Thought problems, social problems, aggressive behaviors were significantly improved.
- Hyperactive/impulsivity as well as inattention symptoms were not statistically significant.

## Acute Aerobic Exercise on Response Inhibition in Adults

#### 2019 fMRI Study

- 46 participants (23 ADHD patients, 23 "Health Control")
  - fMRI machine and asked to perform a Go/No-Go Task after either exercise or the control.

#### Key Findings:

• Patients compared to healthy controls showed exercise-related increases in brain activation during correct inhibition trials in parietal, temporal, and occipital regions.

## Acute Aerobic Exercise on Response Inhibition in Adults

#### Highlights:

- Each participated in aerobic exercise (cycling) vs. watching a soap opera (control)
- Results were compared between groups (patient vs. health control) and within groups (exercise vs. movie).
- Patients with worse initial performance showed greater exercise-related activation increases and improvements in performance.

## Physical Exercise and Functional Outcomes in the Treatment of ADHD

#### 2020 Meta-Analysis

- 10 total studies included (6 Motor Skill Outcomes; 7 Executive Function; n = 300)
  - Included Randomized Control Trials, Quasi-Experimental and Clinical Trials.

#### Key Findings:

• Moderate-to-vigorous PA moderately and significantly improves functional outcomes for children with ADHD when compared to control.

## Physical Exercise and Functional Outcomes in the Treatment of ADHD

#### Highlights

- The majority of interventions used moderate intensity activity (only one used vigorous activity).
- Physical exercise had a somewhat larger effect on motor skills compared to executive functions.
- Effects of exercise on executive function (EF) was moderate and significant, however, results should be interpreted with caution due to "executive function" being a broad conceptual category.

## Effectiveness of Physical Activity Intervention on ADHD Symptoms

#### 2021 Systematic Review and Meta-Analysis

 23 studies (14 two-group control studies and 9 cross-sectional studies. n = 535)

#### **Key Findings**

- Significant improvements in all ADHD-related symptoms
- PA interventions may improve ADHD-related symptoms, especially inattention symptoms.
- Closed-skill and open-skill activities could be beneficial for hyperactivity/impulsivity and inattention symptoms, respectively.

## Physical Activity and Executive Function in Children with ADHD

#### 2022 Systematic Review

• 24 studies (5-18 years old; 1997 - 2019)

#### Key Findings:

- Moderate to vigorous-intensity exercise appears to have a positive effect on executive function in children with ADHD
- Acute and training PA positively influence inhibition and cognitive flexibility

## Physical Activity and Executive Function in Children with ADHD

- Variability because EF includes a variety of components (working memory, inhibition, cognitive flexibility, etc.,)
- Studies used a variety of different PA (e.g., water aerobics, yoga, throwing and catching, jump rope, table tennis, etc.,).
- These findings can be scrutinized due to high risk of bias.
- Dose response using more specific measurement tools (e.g., MET levels) is needed to improve our knowledge of how much exercise is needed to affect EF.

## Exercise on Cognition and Behavior in Children and Adults with ADHD

#### **2017 Systematic Review and Meta-Analysis**

• 29 total articles (4 adults; 25 children/adolescence; n = 959)

#### **Key Findings:**

- Acute and chronic beneficial effects of especially cardio exercise were reported with regard to several cognitive, behavioral, and socio-emotional functions.
- Physical exercise represents a promising alternative or additional treatment option for patients with ADHD.

# The Effects of Physical Exercise in Adults with ADHD

#### 2022 Systematic Review and Meta-Analysis

 10 studies including RCTs, clinical trials and quasi-experiments; only adult (18+) participants (n = 286)

Key Findings:

- Exercise has a small-to-medium positive effect on:
  - ADHD symptoms
  - Executive Function
  - Global Function
  - Mindfulness
  - Motor Functioning
  - Negative Mood
  - Sleep Quality

## The Effects of Physical Exercise in Adults with ADHD

#### Highlights

- Aerobic exercises has the largest significant effect, and walking has a smaller but also significant effect.
- No significant effect for other exercise type including coordinative exercises, kickboxing, Tai Chi or yoga.

## Physical Exercise on Attention Deficits in Children with ADHD

#### 2023 Systematic Review and Meta-Analysis

- 15 randomized control trials (n = 734), ages 5-15 years old.
  - Included both English and Chinese studies.

Key Findings:

• Physical activity was effective for improving motor skills and executive function compared to control.

# Physical Exercise on Attention Deficits in Children with ADHD

- Physical exercise can effectively improve **attention** in ADHD compared with control group
- Hyperactivity was not statistically significant
- **Social problems** was not statistically significant
- Aggressive behaviors was not statistically significant

Closed-skill exercise, 70 min per time, twice a week, and 12–14 weeks altogether showed higher effect size

### Physical Activity on Executive Function in Children and Adolescents with ADHD

#### 2023 Systematic Review and Meta-Analysis

- 24 studies (Included RCTs, crossover trials and non-RCT studies; n = 914)
  - Included RCTs, crossover trials and non-RCT studies
  - 13 closed-motor skills and 12 open-motor skills

#### **Key Findings**

• Exercise improves inhibitory control in children and adolescents with ADHD

### Physical Activity on Executive Function in Children and Adolescents with ADHD

- PA interventions were 2–3 times/week, and the intervention period was generally 8–12 weeks.
- Inhibitory Control: Moderate intensity, open motor skills, chronic and lower weekly exercise amounts.
- Working Memory: Open motor skills, chronic, and higher weekly exercise amounts.
- **Cognitive Flexibility**: Moderate to vigorous intensity, open motor skills, chronic, and lower weekly exercise amounts.

## Optimal Intensity for Improving Executive Function

#### 2024 Systematic Review and Network Meta-Analysis

- 29 studies (Included RCTs, crossover experimental studies, pre- and post-control designs; n = 1231)
  - Only looked at executive functioning outcomes.

#### **Key Findings**

- High-intensity exercise training was the most effective in improving working memory and inhibitory function dimensions, followed by low-intensity exercise training.
- Moderate-intensity exercise training was the most effective in improving cognitive flexibility, followed by high-intensity exercise training.

## Optimal Intensity for Improving Executive Function

#### Highlights:

- Running, cycling, unarmed movement training and cognitive motor training had small effect sizes; Swimming had a large effect size (small number of studies included)
- A medium effect size improvement for those using medication and a small effect size for abstinence from medication and no medication.
- Medication may improve efficacy of physical activity interventions.

## Optimal Intensity for Improving Executive Function

- High intensity exercise had a medium effect size improvement.
- Moderate-intensity and low intensity exercise had small effect size improvement.
- Small effect size for a single training intervention; a medium effect size for less than or equal to 8 weeks and greater than 8 weeks.
- Training frequency of 1-2 times per week had a medium effect size; training frequency of more than 2 times per week had a small effect size.

## **Summary and Conclusion**

- Most evidence is on participants under the age of 18, with a notable skew towards male-dominated samples.
- Most evidence suggests improvements in motor function and executive function.
- $\succ$  Executive function is a broad category of cognitive skills.
- Behavioral function (e.g., hyperactivity, social dysfunction) is inconclusive.

## Recommendations

- Moderate-to-High intensity activity, several times a week for 8+ weeks.
- Open motor skills; aerobic exercise is most commonly studied (but this may be due to the age of participants).
- Those with more severe symptoms may benefit the most from intervention.

## RCTs are Being Run and Published on Exercise for Adults Recently

• Dinu, L., Singh, S., Baker, N., Georgescu, A., Singer, B., Overton, P., & Dommett, E. (2023). The effects of different exercise approaches on Attention Deficit Hyperactivity in adults: a randomised controlled trial.

Likely that we will have more precise data for Adult populations.

## Physical Activity for ADHD

Part 2: Mechanism of Action



### **Theoretical Mechanisms of ADHD**

- Acute and chronic differences in cognitive performance seen in both clinical and non-clinical population.
- Exercise, physical activity and movement may alleviate symptoms in the short and long-term.
- May make ADHD symptoms easier to manage but may not ameliorate neurological differences entirely.
- Exercise and physical activity may be Neuroadaptive, meaning they support brain function and development.

## Neuroadaptive Effects of Physical Activity

- > Neurochemical Changes
- Changes in Brain Structure
- Changes in Brain Connectivity

## ADHD Symptoms Reflect Deficits in NCF including EF and Attention

ADHD is associated with lower performance in tests **Neurocognitive functions (NCF)** of :

- response inhibition, behavioral inhibition, reaction time variability, cognitive flexibility, choice impulsivity, working memory
- Exercise might constitute an avenue to relieve symptom by improving these NCFs

## **Reward Processing Theory of ADHD**

**Maturation Delay Hypothesis:** Hypothesis that ADHD is characterized by a delay in brain development compared to neurotypical individuals.

**Reward Processing Theory** (Alexander & Farrelly, 2018): exercising catalyses the secretion of catecholamines (i.e., dopamine & norepinephrine) that improve the functions of the executive network in the brain.

- This mechanism is also similar to that of prescribed stimulant use for people with ADHD.
- Cognitive load associated with engaging in physical activity and exercise could entail training of impaired cognitive functions.

## Exercise is a Psychostimulant that Can Improve Cognitive Performance

- PA and exercise exert a plethora of beneficial physiological, psychological, and neurocognitive effects including positive influences on cognition, executive and memory function (Hillman, Erickson, & Kramer, 2008).
- Exercise may act as a neuro-enhancer and improve cognitive performance through acute and long-term effects on:
  - Monoaminergic transmission
  - Neurotrophic signaling
  - Mechanisms of neuroplasticity

## Fitness Level Is Associated with Better Cognitive Performance

- "The association between PA and cognitive functions across the general population appear robust, although causal relations cannot be assumed."
- Children with ADHD are less likely than their peers to meet recommended levels of PA.
- "Young individuals with ADHD who are unmedicated, are more likely to be sedentary." (Christiansen et al., 2019)

## Structural Cortical, Cerebellar, and Subcortical Abnormalities

- "ADHD pathology is complex, and several neurophysiological abnormalities contribute to low performance in test of NCFs".
- Structural abnormalities in the cortex and midbrain associated with ADHD likely develop slowly over time.
- MRI and fMRI imaging of the brain show a link between the integrity of key brain structures and ADHD symptomatology.

## Structural Cortical, Cerebellar, and Subcortical Abnormalities

- Findings emphasize the role of monoaminergic signaling in cortical regions involved in executive functions.
- Findings provide a structural basis for the prevalent hypothesis that dysfunctions and delayed development of brain circuitries contribute to ADHD.

## Exercise Leads to Structural Changes in the Brain

- Exercise may trigger a cascade of molecular neuroplastic processes eventually leading to structural adaptation in the nervous system.
- Higher fitness levels are associated with both structural and functional differences in multiple cerebral structures, which are intimately involved in cognitive function.
- Some findings suggest that higher-fit individuals outpace their less-fit peers in some neurodevelopmental progress.

## Acute Exercise can Improve Performance on Cognitive Tasks

- Several studies report positive effects of acute exercise on performance on several tests of cognitive function in children with and without ADHD.
  - Positive effects on attention and inhibitory control
  - Cognitive flexibility
- Children with ADHD are likely to benefit the most from acute exercise.

## Chronic Physical Fitness Positively Affects Cognitive Performance

- Long-term exercise improves performance in cognitive tests
- Meta-analysis of the causal effect of long-term exercise interventions on cognitive function in population-based control children finds **small effects on EFs and large effects on attention**.
- Long-term studies of the effects of exercise and physical activity on measures of performance in cognitive tests demonstrate positive effects in both PBC children and children with ADHD.

## Summary of the Research

- $\succ$  Vast majority of the research is in children and adolescents.
- > Majority of the research looks at closed-skill aerobic exercise.
- Executive function improves in both clinical and nonclinical populations with clinical populations showing greater improvement.
- Research with Adult ADHD is promising, but still in its infancy.

## Summary of the Research

- Symptoms associated with ADHD can be improved with both acute and chronic exercise with small-to-moderate effect sizes reported in children, adolescent and adult\* populations.
- Along with medication and meta-cognitive skills, exercise is a promising adjunct treatment and lifestyle medicine option for the management of ADHD.

#### Neurochemical Characteristics

Abnomal forebrain and cortical monoaminergic transmission affecting attention and reward processing <sup>252, 253, 254, 262, 275</sup>

#### Functional CNS Characteristics

- 'Cortical Slowing': higher TBR, lower αpeak freq.<sup>175</sup>
- Inhibition, attention and reward related hypoactivity in ACC, PC, PFC, STR 180, 181, 183, 184
- Hyperactivity in default networks<sup>180</sup>
- Decreased TR P300 amplitude<sup>200</sup>

#### Structural CNS Characteristics

- Lower GM volume in BG<sup>130, 138, 139, 141</sup>, FrC<sup>138, 139</sup>, CB<sup>136, 138</sup>, TC<sup>130, 139</sup>, PC<sup>130, 139</sup>
- Lower Frontal cortical thickness<sup>132</sup>
- Lower WM integrity in FAc<sup>141</sup>, FP<sup>142</sup>, UF<sup>142</sup>, CR<sup>142</sup>

#### Effects of Acute Exercise

- STR DA & NE activity △ 283-285
- PFC NE △<sup>290</sup>

B

- Peripheral BDNF, DA and NE △<sup>260</sup>
- PFCTR activity △ 208-214
- FC or RN and integration of EN, DAN and VAN △<sup>205</sup>
- P300 amplitude △76, 78, 82
- TBR <sup>7204</sup>
- Peak α-frequency∆<sup>200</sup>

#### Effects of Chronic Exercise

- STR DA activity △, through DRD2 
  <sup>295</sup> and TH △<sup>292</sup>
- CrB NE activity △<sup>296, 297</sup> through PFC NET expression ▽<sup>298</sup>
- TR activity in PFC and ACC $\triangle$ <sup>216, 218</sup>, PPC  $\bigtriangledown$  216, 217, 218
- P300 amplitude △<sup>219</sup>
- TBR ▽<sup>203</sup>
- Associations point to GM in DS △<sup>90</sup>, PFC △<sup>156</sup> and CC, CR and SLF WM integrity and myelination △<sup>94</sup>, cortical thickness ▽<sup>160</sup>
- Dendritic spine density in PFC△<sup>154</sup>
- UF WM Integrity △<sup>164</sup>



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