The Relation of Childhood Fitness to Brain Health, Cognition, and Achievement

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#### THE HOLISTIC BENEFITS OF PHYSICAL ACTIVITY ARE NOT FULLY RECOGNIZED

#### **INTELLECTUAL CAPITAL FINANCIAL CAPITAL PHYSICAL CAPITAL** IMPROVEMENTS IN: PREVENTION/ TREATMENT OF: IMPROVEMENTS IN: IMPROVEMENTS IN: General motor skills Educational attainment Income Metabolic syndrome/ Functional fitness/ School engagement Job success Type 2 diabetes Physical appearance Productivity/Job performance Processing speed Overall mortality Cardio respiratory Executive function/Inhibition/ Morale/Commitment/Turnover Cardiovascular fitness Mental flexibility Presenteeism disease Muscular strength Memory Coronary heart **REDUCTION IN:** Adiposity/Body Academic performance disease Health care costs composition Brain structure and function Hypertension Absenteeism Lipid profile Concentration/Attention/Impulse control Stroke Bone health/ Learning Colon & breast Osteoporosis cancer ADHD management loint health Lung, endometrial, Age-related cognitive Maternal & infant ovarian cancers decline management health Back pain **Rehabilitation & REDUCTION OF:** recovery Falls Immune system Smoking function Teen pregnancy Sleep patterns Risky sex Nutrition/Diet Drug use Addiction Suicide INDIVIDUAL CAPITAL SOCIAL CAPITAL **EMOTIONAL CAPITAL** IMPROVEMENTS IN: IMPROVEMENTS IN: Social norms • Fun, enjoyment, satisfaction Social network/ Feeling good Positive relationships Self esteem INDIVIDUAL CAPITAL Social status/Social commitment Self efficacy Social inclusion & acceptance IMPROVEMENTS IN: Body image Activity knowledge and skills Trust/Teamwork/Collaboration Intrinsic motivation for physical activity Social skills/Life skills/ Civic participation Mood Non-cognitive skills Gender equality PREVENTION/TREATMENT OF: Sportsmanship Equity for persons with disabilities Stress Time management Crime, juvenile delinguency Depression Goal setting & gang participation reduction

- Community cohesion
- Peace/Understanding/Recovery
- Bridging differences (socio economic status, racial, ethnic, disability, religious, sexual)
- Safety & support

- Initiative/Leadership
- Honesty/Integrity/Respect/ Responsibility
- Enthusiasm/Intrinsic motivation
- Commitment/Self discipline/ Self control/Persistence

Anxiety

Nike, Inc. initiated a multidisciplinary input and validation

Copyright Nike, Inc.

# Children are becoming increasingly sedentary.

# Increased prevalence of being overweight and unfit.



### **Military Preparedness**

- The U.S. Department of Defense estimates that as many as 1/3 of military-age youth are ineligible for service due to weight
- Nearly 27% of 17-24 year olds are too overweight to serve
- \$1 billion spent on management of overweight & obesity in recruits

Sedentary Childhood often leads to Sedentary Adulthood.



generations will live less healthy and have

Recent estimates have indicated that younger

shorter lives

than their parents.



(Fontaine et al., 2003; Olshansky et al., 2005)

A growing number of schools are eliminating daily physical activity opportunities to provide additional classroom time on formal academic topics.





Time spent being physically active does not detract from academic achievement.

### **Physical Fitness & Achievement Test** Performance



Castelli, Hillman, Buck, & Erwin (2007) JSEP.

### Aerobic Fitness & Achievement Test Performance



Castelli, Hillman, Buck, & Erwin (2007) JSEP.

### Body Mass Index & Achievement Test Performance



Castelli, Hillman, Buck, & Erwin (2007) JSEP.

# PA Effects on Cognition

- Meta-analyses have determined that PA is positively associated with cognition.
  - Etnier et al. (1997) found an ES = .25 SD for perceptual, cognitive, & motor tasks.
  - Colcombe & Kramer (2003) observed that this relationship was greater for tasks requiring extensive executive control (ES = .5 SD).
  - Recent meta-analyses (Lambourne & Tomporowski, 2010; Smith et al., 2010) corroborate this beneficial relationship.

![](_page_12_Figure_5.jpeg)

## **Executive Control**

- Executive control is required to meet desired outcomes and intended goals.
  - Situations in which executive control is required include:
    - Novel tasks, planning, problem solving, conscious choices among alternatives, overriding a strong internal or external pull, etc.
- Core cognitive abilities that constitute what collectively is known as executive function include (Diamond, 2006):
  - Inhibition the ability to ignore distraction & stay focused
  - Working memory the ability to hold information in mind and manipulate it
  - Cognitive flexibility the ability to switch perspectives, focus of attention, or response mappings

## Flanker Task

![](_page_14_Figure_1.jpeg)

![](_page_14_Picture_2.jpeg)

<u>\_</u>~

![](_page_14_Picture_3.jpeg)

![](_page_15_Figure_0.jpeg)

Chaddock et al. (2010). Developmental Neuroscience, 32, 249-256.

# Event-Related Potentials

![](_page_16_Figure_1.jpeg)

## The P3 Component

P3 represents the updating of attention and working memory once sensory information has been analyzed (Donchin, 1981).

P3 amplitude reflects changes in the neural representation of the stimulus environment and is proportional to the amount of attentional resources needed to engage in a given stimulus or task (Polich & Heine, 1996).

P3 latency is a measure of stimulus classification speed (Duncan-Johnson, 1981), with longer latencies reflecting increased processing time.

![](_page_17_Picture_4.jpeg)

Stimulus Onset

## Action Monitoring (ERN)

- Error-related negativity (ERN) reflects neuroelectric indices of action monitoring.
- A large negative component of response-locked ERP.
- Generated by the anterior posterior a medial frontal cortex.
- The ERN reflects a cognitive learning mechanism used to correct an individual's incorrect responses during subsequent environmental interaction.

![](_page_18_Figure_5.jpeg)

![](_page_19_Picture_0.jpeg)

# Modified Flanker Task

![](_page_20_Picture_1.jpeg)

![](_page_21_Figure_0.jpeg)

Hillman et al. (2009). Developmental Psychology, 45, 114-129.

# Fitness & Flanker Task Performance

![](_page_22_Figure_1.jpeg)

Hillman et al. (2009). Developmental Psychology, 45, 114-129.

## Fitness & Cognitive Flexibility

![](_page_23_Figure_1.jpeg)

## Fitness & Cognitive Flexibility

![](_page_24_Figure_1.jpeg)

## Fitness & Cognitive Flexibility

![](_page_25_Figure_1.jpeg)

## The FITKids Randomized Trial

An after-school physical activity program occurring on 150 of the 170 day school year.

221 Children (Rx = 109, Control = 112) participated in >70 minutes of intermittent moderate to vigorous physical activity following each school day.

![](_page_26_Picture_3.jpeg)

![](_page_26_Figure_4.jpeg)

## Change in Flanker P3 Amplitude

![](_page_27_Picture_1.jpeg)

![](_page_28_Figure_0.jpeg)

2 μV p = 0.05 3 μV p < 0.01

## Change in Flanker P3 Latency

![](_page_29_Figure_1.jpeg)

# Change Flanker Task Performance

![](_page_30_Figure_1.jpeg)

W

#### Flanker Incongruent P3 Relationship with Attendance

![](_page_31_Figure_1.jpeg)

## Switch Task

![](_page_32_Picture_1.jpeg)

## Change in Switch P3 Amplitude

![](_page_33_Picture_1.jpeg)

![](_page_34_Figure_0.jpeg)

2 μV p = 0.05 4 μV p < 0.001

#### Change in Heterogeneous Response Accuracy 80-Change in Response Accuracy (% Correct) 12 Response Accuracy (% Correct) 10 75 8 70 6 4 65 2 60 0 -Intervention Waitlist Pre Post Time

Switch Heterogeneous Response Accuracy Relationship with Attendance

![](_page_36_Figure_1.jpeg)

## **Acute Exercise**

### Acute Exercise in Preadolescent Children

![](_page_38_Figure_1.jpeg)

Hillman et al. (2009). Neuroscience, 159, 1044-1054.

## **Task Performance**

![](_page_39_Figure_1.jpeg)

Hillman et al. (2009). Neuroscience, 159, 1044-1054.

## Academic Achievement

![](_page_40_Figure_1.jpeg)

Hillman et al. (2009). Neuroscience, 159, 1044-1054.

## **ADHD & Neuroelectric Function**

![](_page_41_Figure_1.jpeg)

Pontifex et al. (in press). J. Pediatrics.

## ADHD & Task Performance

![](_page_42_Figure_1.jpeg)

Pontifex et al. (in press). J. Pediatrics.

#### ADHD & Academic Achievement 120 **Post Reading Post Exercise** \* 115 \* Standard Score 110 105 100Reading Spelling Arithmetic

Pontifex et al. (in press). J. Pediatrics.

### Individual Differences in Inhibitory Control

![](_page_44_Figure_1.jpeg)

### Individual Differences in Inhibitory Control

![](_page_45_Figure_1.jpeg)

![](_page_46_Picture_0.jpeg)

![](_page_47_Figure_0.jpeg)

## Adiposity, Cognition, & Achievement,

![](_page_48_Figure_1.jpeg)

Kamijo et al. (in press). Obesity.

## **Obesity & Inhibition**

![](_page_49_Figure_1.jpeg)

Kamijo et al. (2012). Psychophysiology.

## Obesity & ERPs (NoGo-Go P3 Amplitude)

![](_page_50_Figure_1.jpeg)

Kamijo et al. (2012). Psychophysiology.

## **Obesity & Action Monitoring**

![](_page_51_Figure_1.jpeg)

![](_page_52_Picture_0.jpeg)

#### Fitness & Working Memory 6 Encoding Retrieval \* 4 $\Delta\% VO_2$ ??k?? RKBXL 2 0 4500 ms **S1 S2** -2 -4 **FITKids** Control Intervention **1** Letter **3 Letters 5** Letters 80 Response Accuracy (%) 2 2 0 2 2 0 8 0 2 2 0 8 Response Accuracy (%) 75 70 65 60 55 Intervention (20) 50 Waitlist (16) 45 45 45 Pre Post Pre Post Pre Post

Kamijo et al. (2011). Dev. Sci., 14, 1046-1058.

#### **Picture Encoding**

![](_page_54_Picture_1.jpeg)

![](_page_54_Picture_2.jpeg)

![](_page_54_Picture_3.jpeg)

![](_page_54_Picture_4.jpeg)

5 minute Delay

#### **Retrieval Task**

![](_page_54_Picture_6.jpeg)

![](_page_54_Picture_7.jpeg)

![](_page_54_Picture_8.jpeg)

![](_page_54_Picture_9.jpeg)

# Fitness & Relational Memory

![](_page_55_Figure_1.jpeg)

Chaddock et al. (2011). MSSE, 43, 344-349.

## **Relational Memory Task**

![](_page_56_Figure_1.jpeg)

![](_page_56_Picture_2.jpeg)

#### Retrieval

![](_page_57_Figure_0.jpeg)

Chaddock et al. (2010). Brain Research, 1358, 172-183

## Virtual Crosswalk

Why do we care about attention and memory performance in children?

•

- Motor vehicle accidents are among the leading causes of death among children under the age of 16 years in the U.S.
- Given the importance of fitness to cognition, might fitness lead to better decision making at the crosswalk?

Chaddock et al. (2012). MMSE, 44, 749-753

![](_page_58_Picture_5.jpeg)

## Conclusions

- Fitness may benefit brain health and academic performance.
- Fitness has been linked to changes in cognition that are disproportionately larger for tasks requiring cognitive control.
- Early PA experience may shape cognition and its neural underpinnings.
- Excess adiposity is related to decrements in cognitive & brain health, and scholastic achievement.
- Single bouts of aerobic exercise benefit basic and applied aspects of cognitive performance.
- Collectively, these data suggest that time spent engaged in physically active does not detract from academic performance.
- Thus, early intervention is crucial toward lifespan health and effective function of brain and cognition.

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![](_page_60_Picture_7.jpeg)