Benefits of Physical Activity for Improving Executive Functions: How Important are the Cognitive, Social, and Emotional Aspects?

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Some of the most important abilities both for HAPPINESS and for SUCCESS in school and in life are EXECUTIVE FUNCTIONS

The 3 core Executive Functions are:
- Inhibitory Control
- Working Memory
- Cognitive Flexibility
Inhibitory Control

Involves resisting a strong inclination to do one thing, and instead do what is most appropriate or needed.

(a) Selective or Focused Attention:

- Being able to concentrate, ignore distractions, & pay attention
- Critical for staying focused and on task

Focused Attention

Examples: Singing a song as a Round or Focusing on what one person is saying when many people are talking
(b) **Self Control**: being able to give considered responses rather than impulsive ones, resisting temptations. Critical for complying with societal norms and not doing things you’d regret.

**Inhibitory control at the level of behavior:**

- Self-control saves us from putting our foot in our mouth or making a social faux pas.
- Think of all the trouble you would get in if you...
  - blurted out the first thing that came to mind,
  - grabbed whatever you wanted without asking or paying, or
  - did other socially inappropriate or hurtful things.

  If we want to change, if we want to mend our ways, we need self-control.

**Research shows that**

children with better inhibitory control (i.e., children who were more persistent, less impulsive, & had better attention regulation) later as teenagers, were LESS likely to

- make risky choices,
- have unplanned pregnancies, or
- drop out of school and
as adults 30 years later have...
- better health
- higher incomes and better jobs
- fewer run-ins with the law
- a better quality of life (happier)

than those with worse inhibitory control as young children,
controlling for IQ, gender, social class, & home lives & family circumstances growing up across diverse measures of self control.

That’s based on a study of 1,000 children born in the same city in the same year followed for 32 years with a 96% retention rate.

by Terrie Moffitt et al. (2011)

Working Memory involves:
Holding information in mind to work or play with it
Critical for reasoning and creatively seeing connections among ideas or facts
Working Memory also involves holding information in mind while working on something else.

E.g., holding a question or comment in mind as you follow what is currently being said.

Or holding a phone number in mind when someone asks you a question before you have a chance to dial.

Working memory and inhibitory control each independently predict both math & reading competence from the earliest grades thru university often better than does IQ.

(Alloway & Alloway, 2010; Bull & Scerif, 2001; Dumontheil & Klingberg, 2012; Gathercole et al., 2004; McClelland & Cameron, 2011; Nicholson, 2007; Passolunghi et al., 2007; St Clair-Thompson & Gathercole, 2006; Savage et al., 2006; Swanson, 2014)

Cognitive Flexibility involves being able to flexibly adjust to changed demands or priorities, see things from new and different perspectives.

Critical if one is to creatively think outside the box.
An example of poor cognitive flexibility:
When one door closes, another door opens;
but we often look so long and so regretfully upon the closed door, that we do not see the ones which open for us.
- Alexander Graham Bell

If there’s a problem that we haven’t been able to solve, can you ‘think outside the box’ to...
...conceive of the problem, frame the problem, in a new way?
...come up with a completely different way of attacking it?

If you always do what you always did, you’ll always get what you always got.
- Einstein
Can you creatively see the same thing from different perspectives?

For example, what unusual uses can you think of for a TABLE?

You could hide under it.
Turn it on its side to keep a door closed.
Turn it upside down to play horseshoes.
Use it as a percussion instrument.
Cut it up for firewood.

In what way is a carrot like a cucumber?
In what way is a carrot like an orange?
In what way is a carrot like a potato?
In what way is a carrot like an apple?
In what way is a carrot like a cucumber?
In what way is a carrot like an orange?
In what way is a carrot like an apple?
Karen Pape, MD:
“Habit Hides Recovery”

By thinking outside the box, Dr. Pape has been able to help children with motor coordination problems when everyone else had given up:

www.devcogneuro.com/videos/
Karen_Pape_composite_42min_52sec.mp4

The 3 core Executive Functions are:

• Inhibitory Control
• Working Memory
• Cognitive Flexibility

Higher-order Executive Functions are:

• Problem-solving
• Reasoning
• Planning

Executive Functions
are important for every aspect of life – success in school and in the workplace, making & keeping friends, marital harmony, and avoiding things like unplanned pregnancy, substance abuse, or driving fatalities.

In other words, self-control, creativity, reasoning, mental flexibility, discipline and perseverance are really important – they are often more predictive than IQ.
Adele Diamond
2013
Executive Functions.
Annual Review of Psychology,
vol 64, pages 135-168

Confidence
Camaraderie
Ability to work together as a team
Happier
Found something to be passionate about
Gave them a way to be unique (to be special)
Amazingly, no intervention study has yet investigated the benefits of participation in any sport for executive functions.

The different parts of the human being are fundamentally interrelated.
Each part (cognitive, spiritual, social, emotional, & physical) is affected by, and affects, the others.

Diamond, 2007

We have to care about children’s emotional, social & physical well-being, if we want them to be able to problem-solve, exercise self-control, or display any of the other Executive Functions.
Executive Functions depend on Prefrontal Cortex and the other neural regions with which it is interconnected.

PFC is the newest area of the brain and the most vulnerable.

If you’re
• sad or stressed
• lonely or
• not physically fit
Prefrontal Cortex and Executive Functions are the first to suffer, and suffer THE MOST.
Conversely, we show better Executive Functions when we’re
• happy
• feel socially supported, &
• we’re healthy & physically fit

Our brains work better when we are not in a stressed emotional state.

Amy Arnsten, 1998
The biology of being frazzled
Science

That’s particularly true for prefrontal cortex and executive functions.
Stress impairs Executive Functions and can cause anyone to look as if he or she has an EF impairment (like ADHD) when that’s not the case.

You may have noticed that when you’re stressed you can’t think as clearly or exercise as good self-control.

Here are some of the neurobiological reasons for why that’s the case.
Stress and Prefrontal Cortex

Even mild stress increases DA release in PFC - but not elsewhere in the brain

(Roth et al., 1988)

In humans (& primates in general)

Prefrontal Cortex has more receptors for CORTISOL than any other area in the brain.

Distribution of Corticosteroid Receptors in the Rhesus Brain.
J Neurosci, 20, 4657-4568

A few weeks of stress in preparation for a major exam disrupts communication between PFC and other brain regions.
(including parietal cortex, anterior cingulate cortex, the insula, and the cerebellum)

Liston et al. (2009) PNAS
When we’re sad we’re worse at screening out irrelevant information (i.e., worse at selective attention).

Desseilles et al., 2009
von Hecker & Meiser, 2005

When we are happy we’re better at selective attention.

Gable & Harmon-Jones, 2008

People show more creativity when they are happy

THE most heavily researched predictor of creativity in social psychology is mood.
The most robust finding is that a happy mood leads to greater creativity (Ashby et al. 1999).
It enables people to work more flexibly (Murray et al. 1990) & to see potential relatedness among unusual & atypical members of categories (Isen et al. 1985, 1987).

It’s not that sadder people are less creative than happier ones, but that an individual tends to be more creative when he or she is happier than when he or she is more miserable.
Our brains work better when we are not feeling lonely or socially isolated.

Loneliness: Human Nature and the Need for Social Connection
2008
a book by
John Cacioppo & William Patrick

That’s particularly true for prefrontal cortex and executive functions.

People who feel lonely, or are focusing on anticipating being alone, show worse EFs than people who feel, or anticipate feeling, more socially supported.

Baumeister et al., 2002
Tangney et al., 2004
Twenge et al., 2002
We are fundamentally social. We need to belong. We need to fit in & be liked. Children who are lonely or ostracized have more difficulty learning.

Take Home Message #1

Intervention studies of the benefits of physical activity for EFs may have been missing the boat by concentrating on isolated skills or exercises.

Studies of activities where there is PASSIONATE engagement & commitment to a shared goal, & that build self-confidence – i.e., that touch children’s hearts & souls – are sorely needed.
The closest thing may be…

Lakes & Hoyt (2004) randomly assigned children in grades K thru 5 (roughly 5-11 years old) by homeroom class to Tae-Kwon-Do martial arts or standard physical education for almost a full school year.

Children assigned to Tae-Kwon-Do showed greater gains than children in standard phys. ed. on all dimensions of EFs studied (e.g., cognitive [focused vs. distractible] and affective [persevere vs. quit] and emotion regulation). This generalized to multiple contexts and was found on multiple measures.
Traditional martial arts emphasize self-control, discipline (inhibitory control), and character development.

In a study with adolescent juvenile delinquents (Trulson, 1986), one group was assigned to traditional Tae-Kwon-Do (emphasizing respect, humility, perseverance, honor as well as physical conditioning). Another group was assigned to modern martial arts (martial arts as a only competitive sport).

Those in traditional Tae-Kwon-Do showed less aggression and anxiety and improved in social ability and self-esteem.

Those in modern martial arts showed more juvenile delinquency and aggressiveness, and decreased self-esteem and social ability.
Whether gains are seen depends on the way an activity is done.

There are now several school programs that integrate physical activity with the teaching of academic subjects. Not only do these get the body moving, but they are more fun. Although no studies of EF benefits, studies report better academic outcomes from these programs traditional lessons (sitting still). Students resoundingly prefer classes with physical activity over traditional classes, and they spend more time on task & are better behaved.

The most heavily researched of these programs is TAKE10! Here, children’s movements are designed to solidify and concretize academic concepts (e.g., marching in place to a story about exploration or doing 2-part muscle contractions to help students understand word contractions). Kibbe et al. (2011) reviewed 10 years of evidence and concluded that the program improves child-ren’s academic performance (grades & standard-ized test performance) and in-class behavior.
Other methods of integrating physical activity and academic instruction also report better academic outcomes from combining movement with lessons than from traditional teaching methods:

Move for Thought (Vazou & Smiley-Oyen, 2014)

movement games (Kubesch & Walk, 2009)

and others (Erwin et al., 2012; Mahar et al., 2006).

We are not just intellects, with emotions and social needs, we also have bodies.

Our brains work better when our bodies are physically fit.

*Nature Reviews Neuroscience* (January 2008)

"Be Smart, Exercise Your Heart: Exercise Effects on Brain and Cognition"

Charles Hillman, Kirk Erickson & Art Kramer

"There is little doubt that leading a sedentary life is bad for our cognitive health."
People who are more physically active and have better aerobic fitness have better EFs.

That’s true for kids: Scudder et al., 2014
Hillman, Castelli, & Buck 2005
and for older adults: Boucard et al., 2012
Voelcker-Rehage, Godde, & Staudinger, 2010

but…. 

Contrary to influential reviews of the benefits of aerobic exercise…. 

Nature Reviews Neuroscience (January 2008)
“Be Smart, Exercise Your Heart:
Exercise Effects on Brain and Cognition”
Charles Hillman, Kirk Erickson & Art Kramer
In particular, the frontal lobe & executive functions that depend on it show the largest benefit from improved fitness.
Aerobic exercise per se (without a cognitive component & perhaps without an emotional &/or social commitment [e.g., riding a stationary bike]) seems to produce little or no cognitive benefit.

Of studies that
• were not simply correlational,
• had a control group, & pre- & post-tests, &
• looked at effects lasting longer than 1 hr (i.e., effects of more than 1 session)…

11 studies looked at EF benefits from aerobics per se (aerobics without any cognitive component)
  8 were with older adults
  3 with children 8-12 years old
8 of these 11 (73%) found almost no benefit.
7 of the 11 studies (64%) found absolutely no benefit to EFs.
One study that included 6 behavioral measures of EFs and the Connors Behavioral Rating Scale for Parents...

found a benefit on only 1 of the 6 EF tests (visuospatial WM on the CANTAB) and 1 subscale of Connors (inattentiveness); no benefit to planning, selective attention (one 2 different measures), memory of sequential order, or logical reasoning from 10 weeks of aerobically-intense PE compared to standard PE

Fisher et al., 2011

Most disappointing:
4 studies looked at multiple EF measures and found no EF benefit at all from their training regimens of aerobic exercise.
For ex., Krafft et al (2014) had overweight 8-11 year-olds do 40 min of aerobic exercise every day for 32 weeks & found no improvement in inhibitory control (anti-saccade task) or selective attention (flanker task) compared to peers assigned to sedentary activities such as art and board games.

Hillman et al. (2014)

The wait-list group started out better & the intervention group caught up. There are no sign. differences in post-test levels.

Sternberg task

Kamijo et al. (2011)
Controls started out better & the aerobic group caught up. There was no sign. difference in post-test levels.

Kamijo et al. (2011)

Only difference is on the trivially easy condition. WHY would controls get worse?
Similarly, two meta-analyses of randomized control trials with older adults found minimal or no EF benefits from aerobic exercise.

Angevaren et al. (2008)

11 intervention studies in older adults w/out cognitive impairment

Smith et al. (2010)

17 intervention studies in older adults
Consistent with the disappointing effects of ‘mindless’ aerobics on EFs is the oft-replicated finding that improvements in aerobic fitness are uncorrelated with cognitive improvements. Meta-analysis: Etnier et al. 2006 review: Kramer & Erickson, 2007.

For example: Katie Davis et al. (2011) randomly assigned sedentary, overweight 7-11 year-olds to no treatment or 20-min/day or 40-min/day of group aerobic games (running games, jump rope, basketball, & soccer).

The high-dose group showed the most improvement EFs. The low-dose group improved as much as the high-dose group on a treadmill test of endurance, but the low-dose group did not improve on EFs significant more than no-treatment controls.
How can the oft-replicated finding that people who are more physically fit have better EFs be reconciled with: Aerobic interventions (even ones that last a year) do little to improve EFs or memory, and cognitive and physical fitness improvements are uncorrelated?

It could be that the correlation between better physical and cognitive fitness is due to one or more other variables and not to better fitness per se. Perhaps people who are more physically fit have the good sense to eat better or get more sleep, tend to be healthier in general.

Or, maybe causality goes in the opposite direction since one probably needs good EFs, especially good inhibitory control and discipline, to maintain a regular exercise regimen. At least the evidence so far seems to indicate that it is not the aerobic fitness itself that is causing the cognitive benefit.
Many people who maintain better fitness do so by participating in physical activities that involve cognitive challenges and complex motor skills (such as ultimate Frisbee, squash, tennis, rock climbing, soccer, beach volleyball, social dance or martial arts).

Maybe people who freely choose to do aerobic activities enjoy them more than people who are randomly assigned to them.

**There’s evidence that any benefit of physical activity for cognition may be proportional to how much joy the physical activity brings** (Hill et al., 2010; Raichlen, Foster, Gerdeman, Seillier, & Giuffrida, 2012; Heyman et al., 2012; Wolf et al., 2010).

Boring exercise is particularly unlikely to yield cognitive benefits.

Many people who maintain better fitness do so by participating in activities that engage their minds & their hearts & souls – they may be passionate about these activities and deeply committed to them. These activities may be an important aspect of participants’ social lives & their lives in general, these activities may be an important source of pride and personal identity.
Results for interventions with more emphasis on motor skills and cognitive demands (more components of sports activities) have been only slightly better than for aerobic exercise or resistance training interventions.

Katie Davis et al. (2011) sedentary, overweight 7-11 year-olds random assignment no treatment, 20-min/day or 40-min/day of group aerobic games (running games, jump rope, basketball, & soccer)
On their most difficult EF measure, the high dose aerobic group performed better than controls.

Mirko Schmidt, Katja Jäger, Fabienne Egger, Claudia Roebers, & Achim Conzelmann 2015 Cognitively Engaging Chronic Physical Activity, but Not Aerobic Exercise, Affects Executive Functions in Primary School Children: A Group-Randomized Controlled Trial Journal of Sport & Exercise Psychology vol. 37, p. 575 -591
### Team Games
(High Cognitive Engagement, High Physical Exertion)

Specifically designed team games (floorball and basketball) to challenge EFs. Both team games required lots of prospective control, complex eye-hand coordination, & goal-directed behavior. Combined sport-specific skill development w/ enriched cognitive engagement.

For example, while children were playing basketball, the teacher suddenly blew the whistle, meaning of some rules of the game changed immediately. **Later a** visual signal was added to the acoustic one.

For ex., the combination of hearing a whistle and seeing a red card meant a change in the rules whereas the combination with a green card meant that the learned rules remained in force.

Each lesson started with an EF demanding warm-up. For ex., a game of tag was played in which children had to keep in mind different rules, react appropriately to acoustic cues, inhibit prepotent responses, & shift between different situations & rules.

### Aerobic Exercise
(High Cognitive Engagement, High Physical Exertion)

The attempt was made to choose exercises that were not cognitively demanding. For ex., children were to run a marathon as an entire class, whereby each child was allowed to cross off one box from a joint list after each circuit.

Music was played in the background. Exercises were chosen so that the motivation of the children could be maintained for as long as possible. Also tried to match the team games in terms of physical intensity & amount of social interaction.
but the programs lasted only 6 weeks and had only 2 sessions per week (only 12 sessions total) 45 min each (10-12 year olds, about 63 per group)
9 - 10 year olds (N= 71) were randomly assigned to:

- **aerobic exercise**, **motor coordination**, or **control group**
- 3x/week for 10 weeks (30 sessions total)
- @ 45 minutes after school

The control group received assisted homework sessions.

**The aerobic intervention** focused on running and running-based games of moderate to vigorous intensity

- The motor coordination intervention focused on balance and bilateral, hand-eye, & leg-arm coordination (e.g., bimanual coordination where the hands performed complex temporal &/or spatial tasks)
- Plus spatial orientation & reaction to moving objects/persons.
- It was highly varied & designed to continue to be challenging.
- Different balls, rackets, skipping ropes, speed ladders, balance pads, etc. were used.
- These tasks activate frontal and parietal regions.

**Method**

**Random assignment to:**

- **aerobic exercise group (AEG)**
  - intensity: 60-70% of \(HR_{\text{max}}\)

- **coordinative exercise group (CEG)**
  - intensity: 55-65 % of \(HR_{\text{max}}\)
Koutsandreou et al., 2016

Improving Children’s Coordinative Skills & Executive Functions: The Effects of a Football [soccer] Exercise Program
Alesi et al. (under review)
Perceptual and Motor Skills
Corsi Blocks (spatial span) pre post

Soccer Group
Sedentary Group

Corsi Blocks (spatial span) pre post

Soccer Group
Sedentary Group

Tower of London

More difficult & more clearly a test of EFs

Koutsandréou et al., 2016

Homework Control Group
Chang et al. (2013)
The Impacts of Coordinative Exercise on Executive Function in Kindergarten Children
*Experimental Brain Research*, 225, 187-196
randomly assigned children to low-intensity or high-intensity soccer exercise
Both groups improved in accuracy & speed on the flanker task with almost identical post-test results & pre-to-post improvement
Since both groups showed comparable improvement, we don’t know if exercise played a role in the improvement.
To conclude that we’d need a 3rd group that did not do soccer practice, and did not show comparable improvements.
(i.e., need differential improvement)

Bittmann, Gutschow, Luther, Wessel, & Kurths (2005)
On the Functional Relationship between Postural Motor Balance and Performance at School
*Deutsche Zeitschrift Für Sportmedizin*, 56, (10)
found highly significant differences in balance regulation between better and worse students.
They were able to discriminate good pupils from poor pupils with 80% accuracy based on their balancing skills.

Children with poorer EFs (i.e., those w/ ADHD) show more sway when tested for balance than control children
either with their eyes closed (no visual input), or when on a foam pad (less somato-sensory input).
I.e., they seem to have problems when required to rely on vestibular input.

Zang et al. (2002)
*Chinese J of Clinical Rehabilitation*
Raver et al. (2008) found the ability to walk on a balance beam to be a particularly sensitive measure of EFs in very young children.

People such as Sally Goddard Blythe (of the Institute for Neuro-Physiological Psychology) and Jan Piek (Curtin University, Perth, Australia) have predicted a relation between postural stability and EFs / academic success.

**Associations between Balance, Physical Activity, Physical Fitness and Academic Results in School Children**

submitted to *Developmental Psychology*

**THIS IS THE FIRST STUDY** I know of to look at the relation between difficult balance (frontal plane dynamic postural stability on an unstable platform in a semi-tandem stance), aerobic fitness, physical activity, & academic performance.
The study is only correlational, but the sample is large (853). I think it is worth following up.

Children mean age of 12.3 years
Grade 6 in Australian primary schools
(part of the Lifestyles of our Kids [LOOK] study)
Frontal plane dynamic postural stability during balance on an unstable platform in semi-tandem stance postures (but not in normal standing position) was strongly related to performance on Australian national education tests.

They found that children in the top 25% for semi-tandem aerobic physical
dynamic fitness activity
postural stability
averaged summed test scores
70  51  18
points higher than children in bottom the 25%

A promising approach with encouraging initial research that deserves more study is Bal-A-Vis-X® (Hubert, 2007; Groenendyk, 2008).

It emphasizes eye-hand coordination and balance, often working with another person, and also ear-hand coordination and rhythm.
Bal-a-Vis-X

- developed in 1999 by Bill Hubert in Kansas
- a series of 300 exercises, most of which are done with sand-filled bags and/or racquetballs
- throwing & catching; balancing (with balance boards)
- thousands of mid-line crossings in three dimensions
- deeply rooted in rhythm: “enables the whole [body] to experience the natural symmetrical flow of a pendulum”
- require full-body coordination & focused attention
- becomes increasingly complex
- done throughout a school year - not just for a few months

you can see the exercises at:
http://integratedbrain.co.uk/player.html?filename=video/Bal_Intro.flv
www.intergratedbrain.co.uk
www.bal-a-vis-x.com

Another extremely promising approach, which includes rhythmic movement, bimanual coordination, working together with others, music, and provides joy is drumming
(Ho, Tsao, Bloch, & Zeltzer, 2011; Metzler-Baddeley et al., 2014)
There’s NO evidence that Brain Gym improves cognitive or academic performance, which doesn’t mean Brain Gym doesn’t; there’s just no evidence that it does.

Developmental Cognitive Neuroscience.
vol 18, pages 34–48
and in a forthcoming chapter in an Oxford University Press book

Diamond, A. & Ling, D. (forthcoming)
Fundamental Questions Surrounding Efforts to Improve Executive Functions
The first review to look at all the different methods (e.g., cog. training, phys. exercise, etc.) and at all ages (children thru elderly).
An Integrative Approach to Cognitive & Working Memory Training
We did NOT look at studies that...
...were solely correlational,
...included no comparison group,
...looked only at acute effects (immediate effects of a single exposure), or
...did not assess EFs.

Regardless of the program to improve EFs, a few principles hold:

1. EF training appears to transfer, but the transfer is narrow.
   
   Wide transfer does not occur.
   (On the rare occasions where it has been found, those findings have not been replicated).
People improve on the skills they practice & that transfers to other contexts where those same skills are needed -- but people *only* improve on what they practice – improvement does not transfer to other skills.

If improvement in a particular EF skill is your goal, then you need to engage in activities that require & train that EF skill.

Physical Exercise activities that require thought, planning, concentration, problem-solving, working memory, & inhibitory control will improve those abilities. Those that don’t won’t.
2. You can’t rest on your laurels. Once practice ends, benefits diminish.

EF benefits grow smaller as the time since training and practice increases.

It would be unrealistic to expect otherwise. If you stopped working out, you would not expect to stay in peak fitness forever.

3. Often, benefits are only seen, or are seen most clearly, on outcome measures that push the limits of participants’ EFs.

(e.g., Davis et al., 2007; 2011; Diamond et al., 2007; Manjunath & Telles, 2001; Tuckman & Hinkle, 1986)

Complex, multi-component measures (such as complex-span tasks, Tower of London, or the Wisconsin Card Sort test) which require multiple EF skills are often excellent for distinguishing between groups, though because they require multiple EF skills they are not good for isolating which particular EF skill improved.
4. Whether EF gains are seen depends on the amount of time spent practicing, working on these skills, pushing oneself to improve. Consistent with what Ericsson found is key for being truly excellent at anything.

4a. Duration matters.

2 weeks of resistance training has been found to improve inhibition more than 1 week (Liu-Ambrose et al., 2010, 2012). Similarly, more weeks of computerized cognitive training produces better results than fewer weeks. Perhaps one reason CogMed training has been more successful at improving WM than N-back training is that the duration of CogMed training is longer.
It may be that a year or more is needed, rather than just a few weeks or months.

4b. Dose matters.

Sessions lasting > 30 min seems to be better than < 30 min.

Davis et al. (2007; 2011) found better EF outcomes from longer vs. shorter sessions of aerobic games (40 min vs. 20 min).

McNaughten & Gabbard (1993) also reported greater cognitive benefits from physical exercise for 30 - 40 min versus 20 min.
Similarly, 7 of 9 CogMed training studies (78%) found WM benefits; but only 3 of 9 N-back training studies did. CogMed sessions are generally 30-45 min. N-back sessions are generally only 15-30 min.

5. EFs need to be continually challenged to see improvements - not just used, but challenged.

This is not only true for EF training; it applies to all skills and ages. Consistent with what Ericsson reports is key for being truly excellent at anything - need to keep trying to master what is just beyond your current level of competence & comfort (what Vygotsky called the “zone of proximal development”).
While training and challenging EFs is needed for them to improve that *alone* is probably not enough to achieve the best results.

It’s likely that *indirectly* supporting executive functions by *lessening* things that *impair* them (like stress or loneliness) and *enhancing* things that *support* them (like joy or physical vitality) is also critical.

I suggest having kids do something they can put their heart and soul into.
My thanks to the NIH (NIMH, NICHD, & NIDA), which has continuously funded our work since 1986, & to the Spencer Fdn, CFI, NSERC, & IES for recent support our work - and especially to all the members of my lab.

thanks so much for your attention

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If we want children to do well in school & in life, we need to help them develop healthy exec. functions.

Happily, EFs can be improved at any age from early infancy through old age.

Amazingly, no study that met criteria for inclusion in our review (none) has looked at the possible benefits of aerobic exercise in children younger than 8 or in teens and young and middle-aged adults (ages 13-54 years).
Neither is there a single study of possible EF benefits from activities that train and challenge participants physically (e.g., aerobic capacity) and mentally (e.g., EF skills) in children younger than 5.

The benefit of participation in any sport for EFs has not been investigated. Young children need to move. We predict that movement activities that improve physical fitness and demand diverse motor and EF skills should be very effective in improving young children’s EFs. Will simple aerobic exercise and/or resistance training also be ineffective in

The benefit of participation in any sport for EFs has not been investigated. Young children need to move. We predict that movement activities that improve physical fitness and demand diverse motor and EF skills should be very effective in improving young children’s EFs.
Will simple aerobic exercise and/or resistance training also be ineffective in improving very young children's EFs? No data yet exist that address that.

There has been too exclusive a focus on aerobic running or walking and resistance training; more attention should be paid to physical activities that tax coordination (e.g., Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008; Pesce, 2012; Uhrich & Swalm, 2007), require EFs, and require working with others (Diamond, 2012, 2014; Pesce, 2012).

(By the way, despite its widespread adoption by schools, there is no evidence that Brain Gym® improves cognition. An absence of evidence does not mean that Brain Gym might not, in fact, improve cognition, but it does mean that claims that such benefits have been established are false.)
Exercise alone appears not to be as effective in improving EFs as exercise-plus-character-development (traditional martial arts) exercise-plus-mindfulness (yoga) or other exercise that requires thought (soccer).

Tae-Kwon-Do was found, in the only study to look, to aid the EFs of the oldest children (Grades 4 and 5) most and youngest children (kindergarten and Grade 1) least, compared with standard physical education (Lakes and Hoyt, 2004).

“[T]he importance of the cognitive demands in dynamic sport settings... In team sports where the environment is constantly changing decisions and responses have to be made quickly and accurately.”

Working Memory
Participants need to remember complex play sequences, but not only that....
they must mentally process lots of other info as well,
mentally working with that info, processing in real-time cues about, e.g., opponents’ and teammates’ positions & where they are headed
& the ball’s location and direction of m’v’t.
They compare the present situation with past ones.
They use & update memory to predict future actions on the field.

Inhibitory Control
Inhibition of what might have been their first inclination
Inhibition a planned action when that is suddenly no longer a good idea.
Inhibition of the temptation to try to score oneself rather than passing.

Cognitive Flexibility
The situation on the field is constantly changing. Players must quickly &
accurately respond to those changes,
flexibly switch plans in real time,
flexibly adjusting in real-time to the unexpected.
Planning, Problem-solving, Decision-making, Analyzing, Generating Predictions, Strategizing

Players have to quickly evaluate a situation, evaluate the probability of different possible events, produce new opportunities for what might be done, make quick decisions about what action to take.

Not just ball sports – Archery or Martial Arts are excellent examples
Even competitive runners or swimmers