Effect of physical activity on brain and cognition: Implications for education

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Defining Physical Activity

“Any body movement produced by skeletal muscles that results in a substantial increase over resting energy expenditure”

- Moderate intensity: brisk walking (heart rate 60-70% of max)\(^1\)
- Vigorous intensity: running (heart rate 71-85% of max)\(^1\)

Ekelund et al, 2001\(^1\)
Declining Adolescent Physical Activity

- Proportion of young people completing 60 minutes a day of moderate-to-vigorous physical activity every day falls sharply during adolescence

*Inchley et al. (2015)*
Why is this relevant to education?

Effects on the brain
A Healthy Body and a Healthy Mind

• We know physical activity is good for heart health, bone strength and weight management

• But neuroscience research suggests that physical activity might also improve our brains and our mental abilities
Physical Activity Boosts Our Brains

- Brain cell development - neurogenesis
- Brain capillary growth - angiogenesis
- New connections between neurons - synaptogenesis
- More proteins that help neurons survive – neurotrophins
Testing effects of exercise on brain and cognition
Exercise promotes brain growth

At a cellular level:

**Neurogenesis**

Van Praag et al., 2008

**Synaptogenesis**

Dietrich et al., 2008
Exercise promotes brain growth

At a systems level:

Erickson et al, PNAS, 2010

Thomas et al, Neuroimage, 2016

One year intervention in older adults

Six week intervention in young adults
Activity – Cognition - Attainment?

• Activity can improve attention and memory
  ➢ Over the longer term
  ➢ Immediately after exercise

• Research links physical activity with attainment
  ➢ But we need more and better evidence in schools

eg: Hotting et al 2016; Etnier et al., 2016
eg: Donnelly et al., 2016; Lees & Hopkins, 2013
Why is this relevant to education?

Effects on cognition and academic attainment
Exercise interventions improve cognitive and academic performance **acutely**

**Enhanced response inhibition (flanker)**

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**Improved reading comprehension**

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$n=20$

*Hillman et al, Neuroscience, 2009*
Exercise interventions improve long-term academic outcomes

USA, n=24 primary schools; ~1500 pupils
Physical Activity Across the Curriculum (PAAC)

Donnelley et al, Neuroscience, 2009
Physical fitness associated with better academic performance

From review by Hillman et al, *Nature Neuroscience, 2008*

Disadvantaged children?
- Reduced physical activity
- Reduced neural & cognitive function
- Lower academic performance
Why is this relevant to education?

Psychosocial effects
Activity Can Lift Mood & Maintain Mental Health

• Better physical self-perception and self-esteem
• Reduced depression
• Increased feelings of wellbeing
Activity - Health/Wellbeing - Attainment?

- Mental health and wellbeing are linked to attainment\(^1\) but the mechanisms are not clear:
  - Improved overall self-esteem?
  - Better behaviour?
  - Less absence?
  - More and better sleep?
  - We need more and better evidence in schools

Lees & Hopkins, 2013\(^1\)
What is the current state of physical activity in school PE?
Shaping our Childrens’ Futures...

“Events in early life affect health and wellbeing in later life. Whether this is through changes in genetic expression, how the brain is formed or emotional development…what happens in these years lays down the building blocks for the future. This is particularly the case at times of rapid brain growth in the early years and adolescence.”

Dame Sally Davies, Chief Medical Officer, Annual Report 2012
Physical Activity During School PE

Proportion PE Lesson Spent in MVPA\textsuperscript{1,2}

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\includegraphics[width=\textwidth]{chart}
\caption{Proportion PE Lesson Spent in MVPA\textsuperscript{1,2}}
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Breakdown of Activities During Typical PE Lesson\textsuperscript{3}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{pie_chart}
\caption{Breakdown of Activities During Typical PE Lesson\textsuperscript{3}}
\end{figure}

\textsuperscript{1}Hollis et al, (2017); \textsuperscript{2}Fairclough & Stratton (2005); \textsuperscript{3}Aelterman et al (2012)
Key Stage 3 PE Curriculum Aims

To ensure that all pupils:
• Develop competence to excel in a broad range of physical activities
• Are physically active for sustained periods of time
• Engage in competitive sports and activities
• Lead healthy, active lives
The Fit to Study Trial
Using insight from neuroscience to improve education
• **Aim:** Raise academic achievement, especially in disadvantaged children

• **Means:** A physical exercise intervention

• **Intervention:** Optimise content of PE lessons for brain and cognitive function
Hyp: Improved academic performance in pupils from intervention schools relative to control schools

Secondarily:

- Increased hippocampus-dependent memory performance
- Improved executive function
- Brain changes (increased volume, structural and functional connectivity)
• Year 8 pupils, school-level randomisation
• Intervention
  • Train PE teachers on new programme elements
  • New programme implemented for one year
• Outcomes
  • Primary: performance in maths (NatCen, end Y8)
  • Secondary (Oxford, end Y7 and end Y8)
Secondary measures

- Cognitive tasks
  - Simple reaction time
  - Flanker test
  - N-back
  - Task switching
  - Paired associates memory test

- Questionnaires
  - Attitudes/motivation to exercise
  - Wellbeing, sleep, physical activity
Fitness tests – recorded by teachers, on paper, using familiar methods

Lesson logs: simple, via app or via text, on paper

Activity monitoring during PE – wrist-worn accelerometers, our RAs visit each school 1 day/term

Refining our measures

Questionnaires and cognitive tests – online as homework or in school
Brain imaging sub-study

- N=60 longitudinal cohort (pre and post)
- N=60 replication cohort (post only)
- Structural and functional MRI
- Richer cognitive assessment
- VO2 max fitness test
Measures and pathways

Physical Activity

Fitness

Brain: Attention & Memory

Mental Health & Wellbeing

Academic Attainment

Accelerometer & Lesson Log

Bleep Test

Online Tasks

Maths Test (NatCen)
Timeline

• Development phase: 18m
• Pilot phase: 18m
• Main trial: 12m
Recruitment target: 100 schools

- NFER responsible for recruitment
- Mail-out to 1125 schools with follow-ups
- 104 recruited
Recruited: 104
Randomised: 104

Intervention: 52
- Withdrawn: 13
- At risk: 4
- Evaluation only: 7
- Primary outcome: 35

Control: 52
- Withdrawn: 8
- At risk: 2
- Evaluation only: 1
- Primary outcome: 42
Preliminary baseline results:
Higher fit children: better working memory and relational memory?

Limited practical significance

Thomas Wassenaar
Preliminary baseline results:
More active and healthier children have thicker cortex

Active lifestyle and physical health

Cortical thickness

Dr Piergiorgio Salvan
Challenges

• Scale (100 schools; ~15,000 Y8 pupils)
  • Recruitment
  • Assessments at scale
  • Logistics esp given fixed timeline

• School attrition

• Feasibility and scalability of intervention

• Online testing – school and home IT

• Business as usual control
Conclusions

• There is strong evidence that physical activity influences brain and cognition

• Optimising opportunities for physical activity in school might have benefits not only for physical and mental health but also for academic attainment

• More evidence is required in real world settings and at scale. And these studies are hard to do.
Thank you for listening!

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