Running is Medicine for the Brain

Heather K. Vincent, Ph.D., FACSM
Director, UF Health Sports Performance Center
Director, Human Dynamics Laboratory
Objectives

• Understand how regular exercise affects brain activity and physiology
• Benefits of exercise on cognition, processing and task performance
• Dosage or intensity of exercise on mood, stress reduction and mental health conditions
How do we know that exercise affects the brain?

Neuroimaging studies
- Structural MRI
- Functional MRI (fMRI)

Neural activity

Performance across Cognitive domains
- memory
- processing

Clinical symptoms of health conditions or degenerative disease

Thank our rodent friends for our current knowledge
Why would physical activity impact brain capacity and health?
1. Brain thickness in different regions is higher in people with greater aerobic fitness.

Which preserves: brain size, neuron viability and plasticity

Williams VJ et al. NeuroImage. 2016 dx.doi.org/10.1016
Prefrontal Cortex
• Executive function, getting memories, focus thoughts,
• Attention and learning and concentrate

Hippocampus
• Long term memory function, spatial navigation,
• formation of new memories, detection of new surroundings
• Behavioral inhibition
2. Movement is a continuity of planning and enactment toward a goal...

Which is cognitive function: problem solving, prediction, planning and interpretation!

As we age and participate in training, brain matures and activity patterns optimize.

- Less integrated cognitive performance
  - Diffuse brain activity

- Optimized cognitive performance
  - Localized brain activity
Brain Wiring:

Cortical resilience: better ability to bounce back from a perturbation!

*Lichtman J. Harvard University; tagging individual cells in MRI 2016-2017.*
Brain Chemistry with Exercise

• **Neurotransmitter release**: Serotonin and dopamine

• **Brain-derived neurotrophic factor (BDNF)**: neurogenesis, synapse plasticity and plasticity and cognitive performance

• Release of **endorphins**: euphoria, happiness
Note: Women have lower brain-derived neurotrophic factor (BDNF) response

Due to hormonal fluctuation, exercise during luteal phase will not trigger as high BDNF level as follicular phase

Possible effect on mood and cognition?
Blood Flow
During acute exercise

Blood gas CO$_2$

Cardiac output

Mechanoreceptors may initially $\uparrow$ flow

Blood Flow and Angiogenesis

• Blood flow = neural health
• Acute ↑ regional cerebral blood flow
• Chronic exercise ↑ blood vessel growth (angiogenesis)
• ↑ Cortical capillary density
• Cortex capillary length ↑ 27% and surface area 23%

What dosage does this occur?
• 30 days or longer; 20 min 5 X week 4 months; Even mild exercise ↑ flow

Brain Growth

• Exercise causes neurogenesis

• **Midbrain** (vision and hearing) and **hippocampus** (linked to memory and learning) ↑ in physical size

• In aging, brain atrophies; running reverses some of this size loss!

• **What dose is needed?**
  — 45 min 3 X week of moderate to vigorous exercise
  — 70-80% max HR reserve 2 X week, 6 months

Within the brain, running can:

- Increase Brain size
- Increase Focal activity
- Increase Neurogenesis
- Increase Blood Flow

Cellular reconfiguration
Task Performance
Acute Exercise

ADULTS
• Frontal, medial temporal cortical lobe cognitive functions
• Can last up to 2 hours!
• Squeeze in running for optimal work function

CHILDREN
• 20 min of brisk walking
• ↑ Academic test performance
• Recess or movement breaks between classwork

Creativity: Giving Ideas Some “Legs”

• A moderate intensity workout boosts creative ability for up to 2 hours after
• Even brisk treadmill walking creative output by 60%! Better when outdoors
• Short term training (3 weeks): ↑ curiosity and exploration
• Trained athletes may need the higher exercise intensities to stimulate creativity whereas untrained people are impaired at ↑ intensities

**Memory and Focus**

- Boosts memory and ↑ ability to learn new things
- Running increases focus, multitasking and make distinctions
- ↑ Immediate and delayed memory performance
- **In people:** running can suppress non-relevant information and focus on important things
- **In rats:** running improves spatial learning and memory in focused water-maze tasks
  - Cerebral ischemia = low running exercise can improve memory (object recognition, object location, passive avoidance)

Exception: Too much of a good thing...

After a marathon:
↓ explicit memory task
But ↑ implicit memory

Benefits on Clinical Conditions
Mental Well-Being and Quality of Life

• Strong relationship between mental health domains and exercise

• Wellness instruments (Short Form 36 [SF36] or World Health Organization scores) for perceived:
  — Mental Component
  — Emotional Wellness
  — Vitality
  — Psychological aspect of QOL

This is your brain on jogs.
Stress and Mood: Acute

- Acute jogging or cycling at self-selected pace
  - ↓ Anger, confusion, depression, fatigue, tension
  - ↑ Self-esteem, vigor
- Independent of exercise intensity in low trained people.
- Even 10-15 min of running ↑ pleasantness, ↓ anxiety
- In runners: running at different intensities leads to different cortical activation
  - Intensity = better mood

How about the “moody “ teenager?

- 3 weeks
- 30 min of self-selected running paced, 3 mornings X week → mood and sleep quality, mental concentration and attention

Addiction

• Nicotine, alcohol, food, drugs can release dopamine - so does exercise
• Exercise help become less dependent on these substances.
• Important in addiction recovery efforts
  — Short sessions can distract drug or alcohol addicts
  — Deprioritize cravings
  — Exercise can help “reboot” circadian clock for people whose clock are disrupted by drugs or alcohol
  — Mental health inventories, ↑ neurogenesis!

Anxiety and Depression

What do we know?

• Regular exercisers have lower rates of anxiety and depression
• Running alleviates symptoms in the clinically depressed
• ↑ Resistance to these negative conditions

• One acute bout:
  – Mod-to-high intervals can ↓ anxiety in people
  – Low running speed versus fast speed stimulates serotonin neurons: ↓ anxiety and depression behaviors in rats
Exercise compares to antidepressants as first line treatment for depression.

Anxiety is not reduced to the level where medications are not needed.

Panic Disorder
Social Phobias

Obsessive Compulsive Disorder
Bipolar Disorder

↓ Symptom burden
↑ Well-being
6-10 weeks

Some retention after completion

ADHD Management:

• Attention deficit hyperactivity disorder (ADHD) is related to low frontal cerebral blood flow
  
  Goal: Controlling attention, impulsivity, emotions,
  
  Most studies show improvement in ADHD symptoms; executive function, motor skills, social and affective function

• When combined with medicine, may increase effects!

• Dosage = 2-5 X week, 30-90min per session, 5-12 weeks

Aging Decline in Cognition

• At age 45 decline begins
• Prevent cognitive decline, regular exercise between 25-45 boosts chemical changes
• Recall: BDNF helps with decision making, higher thinking, and learning
• In middle-aged athletes: cognition similar to non-athletes but brains have ↑ metabolic efficiency and neural plasticity
Protection Against Dementia

- Hallmarks of dementia: neuron loss in several brain areas, amyloid plaque development

- **Exercise:**
  - Delays or protects against dementia
  - Inversely proportional relationship between activity and dementia onset
  - Dosage: 3 x or more per (≥15 min sessions)

How Does This Occur?

• ↑ Antioxidant enzymes
• ↑ BDNF, nerve growth factors, vascular factors
• ↑ Insulin like growth factor-1
• ↓ Production of amyloid plaques
• Reorganization of circuits in motor areas and limbic system

• Hippocampus neurogenesis!
• ↑ Synaptogenesis, better learning capabilities

Schizophrenia

- Exercise global cognition; more exercise = better global improvements
- Small to moderate effect on memory, attention, social cognition
- **Dosage:** 20-60 min, 50-75% $VO_2^{\text{max}}$; some programs coupled with resistance exercise or complex movement

Consistency in Running

• Master elite runners took 10 day “Hiatus” (current program: 59km/wk; 5 days/week)
  – Hippocampus and cerebral blood flow ↓ 34-40%!

• In middle aged adults, 6 weeks of running followed by 6 weeks detraining
  – Short and mid-term memory and BDNF ↑
  – Slight decline in both with detraining
  – Stay active!

Summary Points:

• Brain structure, size and working capacity can improve with exercise
• Favorable chemical changes moderate emotion and foster neurogenesis
• Consistent exercise can improve symptoms of several mental health disorders
Thank you!