Sports Related Concussion and Recurring Musculoskeletal Injury

Presented by Dr. Leonard Wright D.C.

Disclosure Statement

- I declare that I have no financial, research, or other affiliations with any organizations, entities, or individuals that could be perceived as having a potential conflict of interest with respect to the content of this presentation. This includes, but is not limited to, affiliations such as consultancies, stock ownership, honoraria, paid expert testimony, patents, or any other financial relationships.

- My presentation is based solely on my professional expertise and I have no conflicts of interest to disclose.

Learning Objectives

1. Describe the biomechanical forces involved in sports-related concussions.
2. Recognize the potential pathways through which concussions can contribute to the development of recurring musculoskeletal issues.
3. Understand the role of altered biomechanics, neuromuscular control, and compensatory mechanisms post-concussion.
4. Understand the clinical presentation, diagnosis, and management of these recurring injuries in athletes with a history of concussions.
5. Discuss strategies for preventing sports-related concussions and subsequent musculoskeletal injuries.
6. Learn about rehabilitation and return-to-play protocols tailored for athletes recovering from concussions to mitigate the risk of recurring musculoskeletal issues.
7. Evaluate current research findings and evidence-based practices related to the prevention, diagnosis, and management of sports-related concussions and recurring musculoskeletal injuries.
8. Discuss the implications of research findings for clinical practice and policy development.

What would happen after this?

Acute Evaluation (0-72 hours)

- ER/PCP
- Glasgow Coma Scale
- CT Scan

Subacute Management

- Stabilize of acute subjective symptoms
  - Cognitive, Vestibular, Oculomotor, Neurological, etc.

Gradual Return to Play

- Clinical Recovery is viewed as complete when the neurological examination and multifactorial assessment have returned to baseline.
- Typical return to play occurs within 16-21 days

Athlete returns to play… all is good, right?

- RTP means the athlete is fully recovered and have no risk or re-injury?
- Not really….
- “In National Football League (NFL) players from 2015 to 2019, the risk of sustaining a subsequent concussion within one year of an initial concussion was found to be between 5.3% to 8.3%, which is similar to the rate of 6.7% reported for same-year repeat concussions in adolescent athletes.” [1]
- What about other injuries follow concussions?

Sports Related Concussion and Musculoskeletal Impact

- Key Take Away:
  - Lower Extremity MSK Injuries Occurred at a higher rate in concussed athletes (45/90 or 50%) compared to non-concussed athletes (30/148 or 20%) ($p < 0.01$)
  - The odds of sustaining a MSK injury were 3.39 times higher in the concussion athletes
  - Number of days lost to injury was similar between concussed and non-concussed athletes [2]

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Concussion May Increase the Risk of Subsequent Lower Extremity Musculoskeletal Injury in Collegiate Athletes

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Sports-Related Concussion and Musculoskeletal Impact

- Key Take Aways:
  - Systemic Review Article
  - Several Studies theorized that neuromuscular control deficits following concussion are associate with these increase injury incidence
  - The period of vulnerability to subsequent injury appears to exist beyond the time of symptom resolution and clinical recovery (16-20 days according to studies) using standard measurement approaches [3]

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Increased Risk of Musculoskeletal Injuries After Concussion

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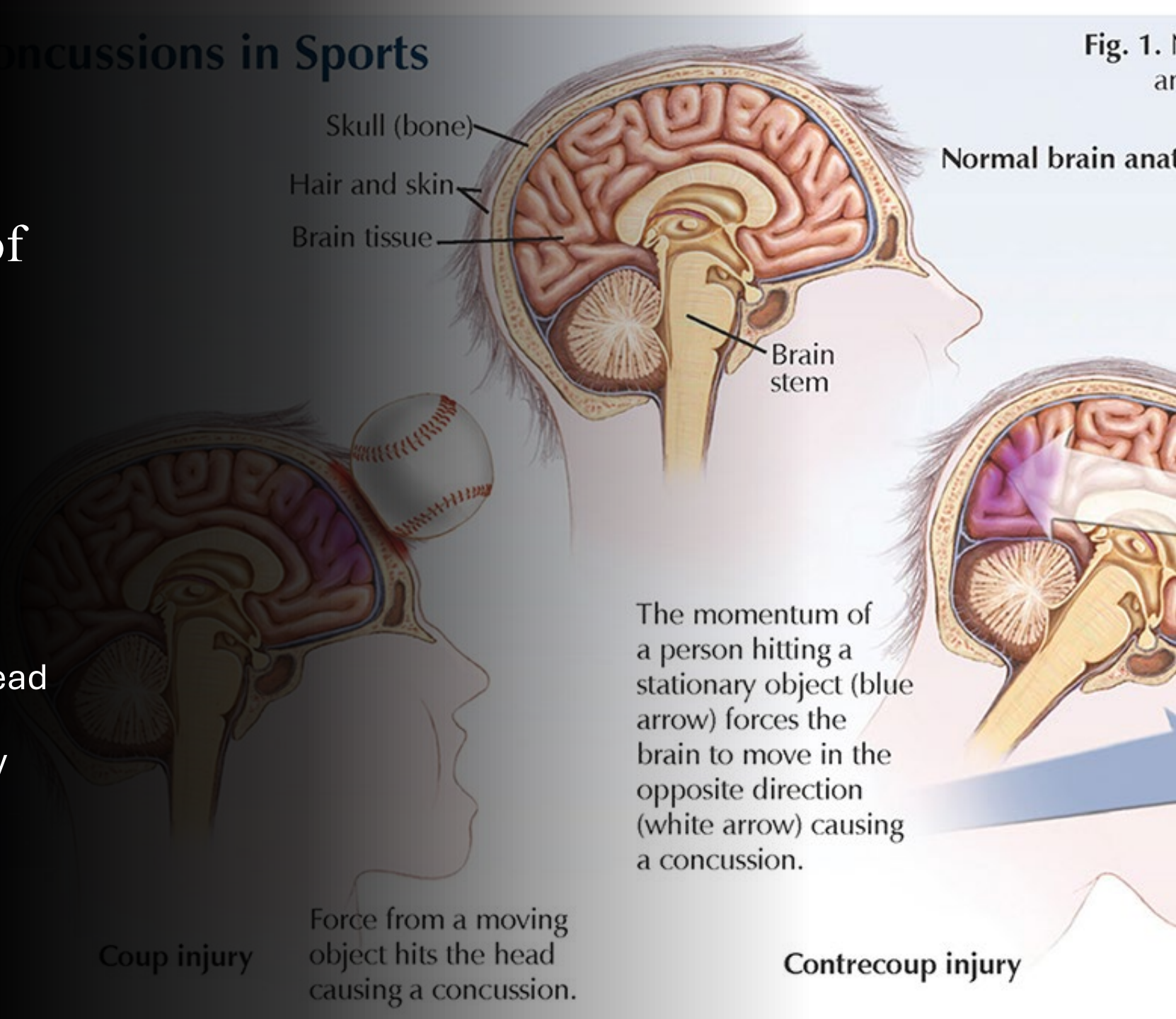
Head Injuries = Increased Risk of MSK Injuries

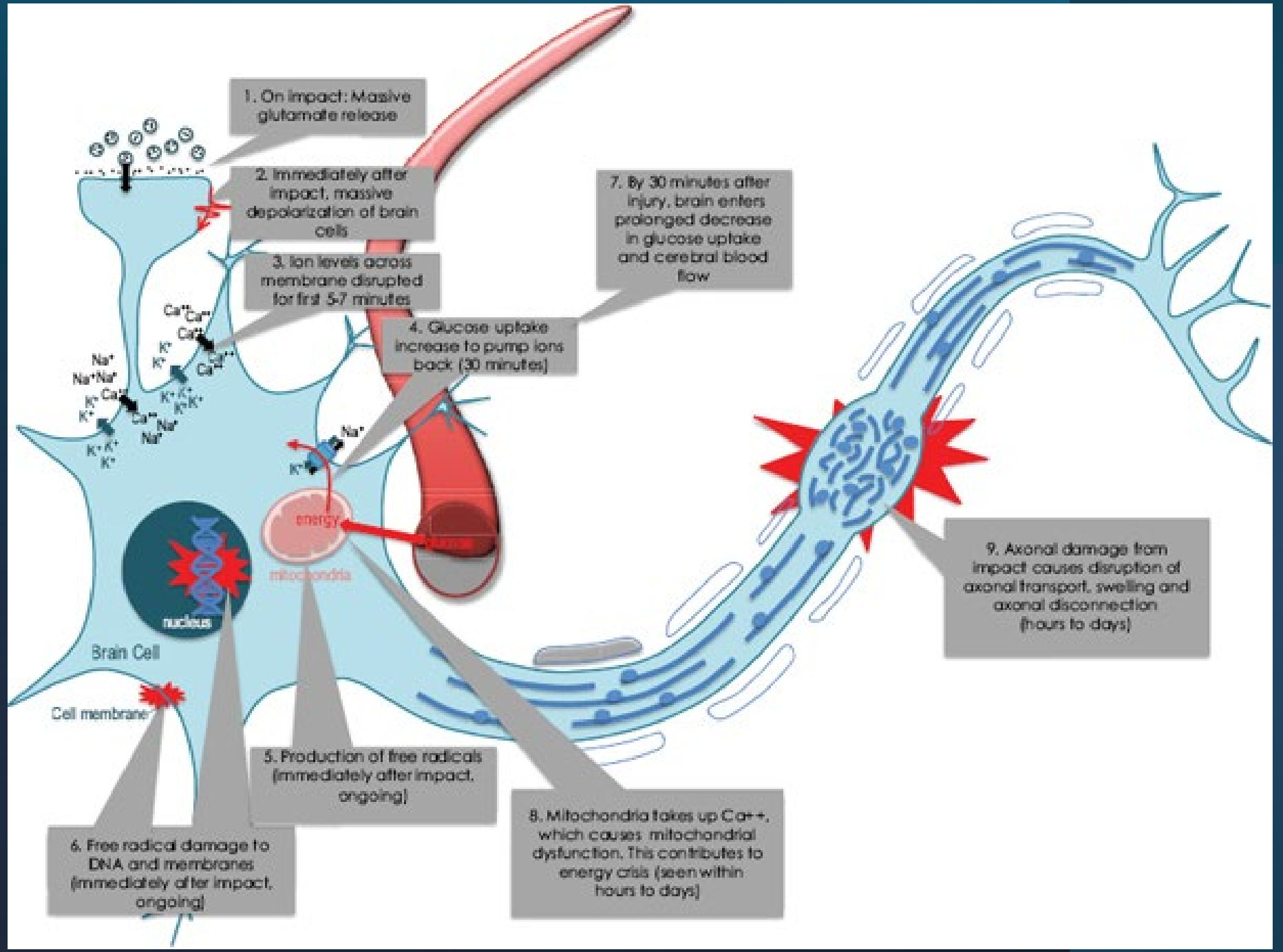
Primary Biomechanics of Concussion in Sport

- Direct Injury (Coup)
  - Falling or hitting head with the ground, ice, opposing player, object, etc.
- Acceleration-Deceleration Injury (Contrecoup)
  - Forces are transmitted to the head and neck following a collision.
  - Common in car accidents, body checks in hockey, whiplashing injuries



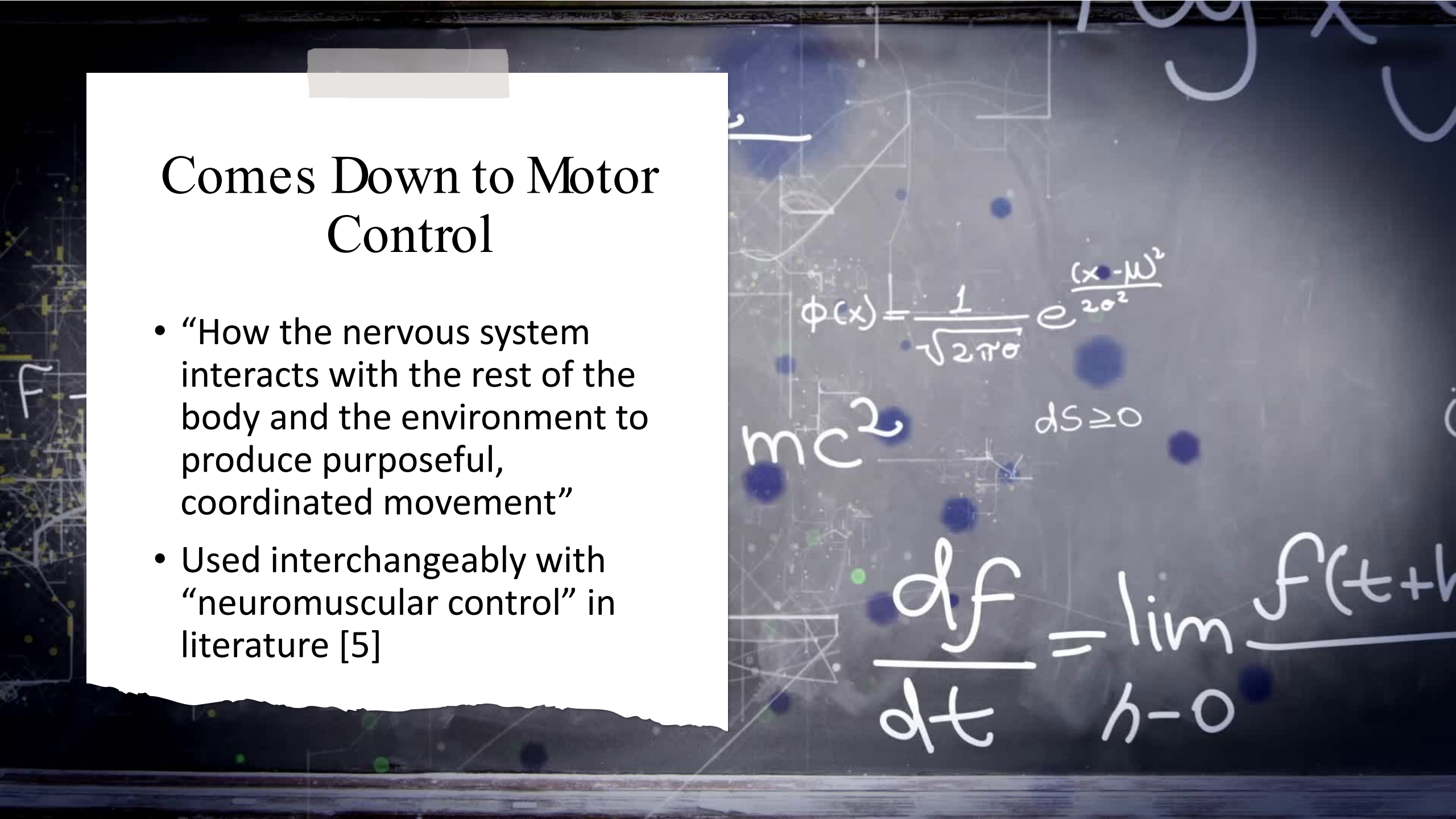
Neurochemistry of Concussive Forces

1. Massive Glutamate Release (On Impact)
2. Massive depolarization of brain cells: (Immediately after impact)
3. Ion levels across membrane disrupted (5-7 minutes)
4. Glucose uptake increase to pump ions back (30 minutes)
5. Production of free radicals (Immediately after impact, ongoing)
6. Free Radical Damage to DNA and Membranes (Immediately after impact and ongoing)
7. Brain enters prolonged decrease in glucose uptake and cerebral blood flow (30 minutes after injury)
8. Mitochondria takes up Ca++ which causes mitochondrial dysfunction (seen within hours to days)
9. Axonal damage from impact causes disruption of axonal transport, swelling and axonal disconnection (hours to days) [4]


1. On impact: Massive glutamate release
2. Immediately after impact, massive depolarization of brain cells
3. Ion levels across membrane disrupted for first 5-7 minutes
4. Glucose uptake increase to pump ions back (30 minutes)
7. By 30 minutes after injury, brain enters prolonged decrease in glucose uptake and cerebral blood flow
9. Axonal damage from impact causes disruption of axonal transport, swelling and axonal disconnection (hours to days)
energy
mitochondria
nucleus
Brain Cell
Cell membrane
5. Production of free radicals (immediately after impact, ongoing)
6. Free radical damage to DNA and membranes (immediately after impact, ongoing)
8. Mitochondria takes up Ca++, which causes mitochondrial dysfunction. This contributes to energy crisis (seen within hours to days)

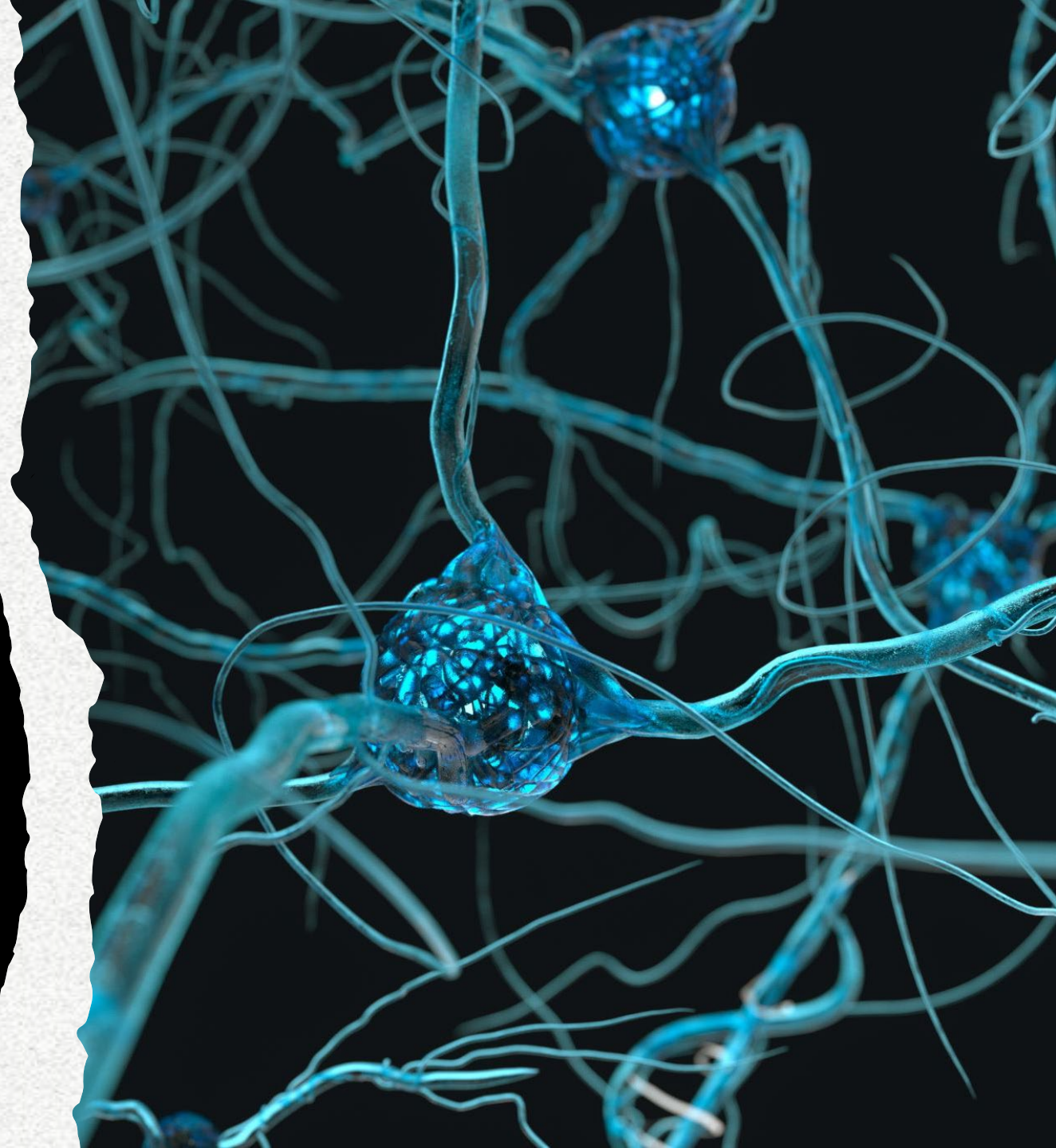
Comes Down to Motor Control

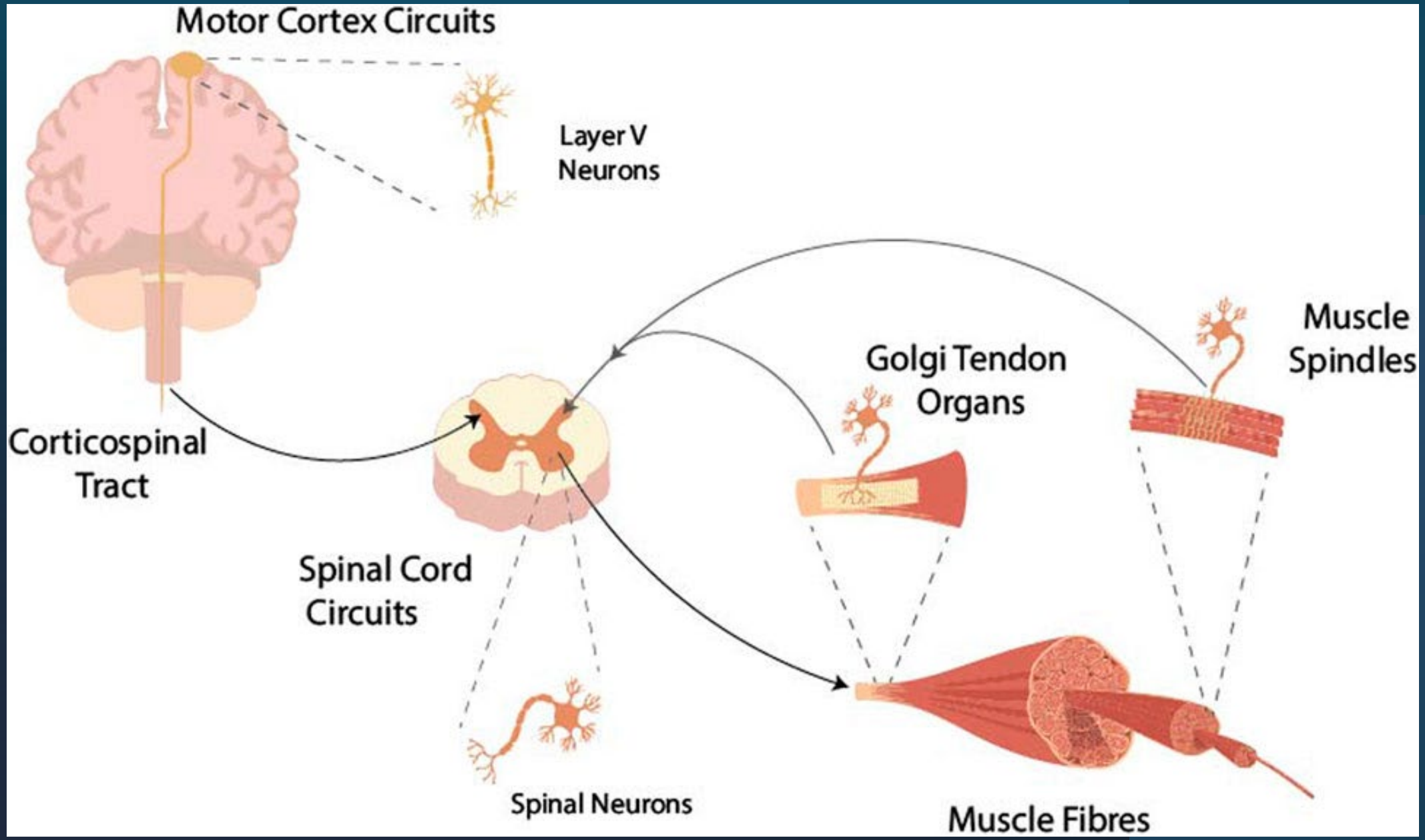
- “How the nervous system interacts with the rest of the body and the environment to produce purposeful, coordinated movement”
- Used interchangeably with “neuromuscular control” in literature [5]



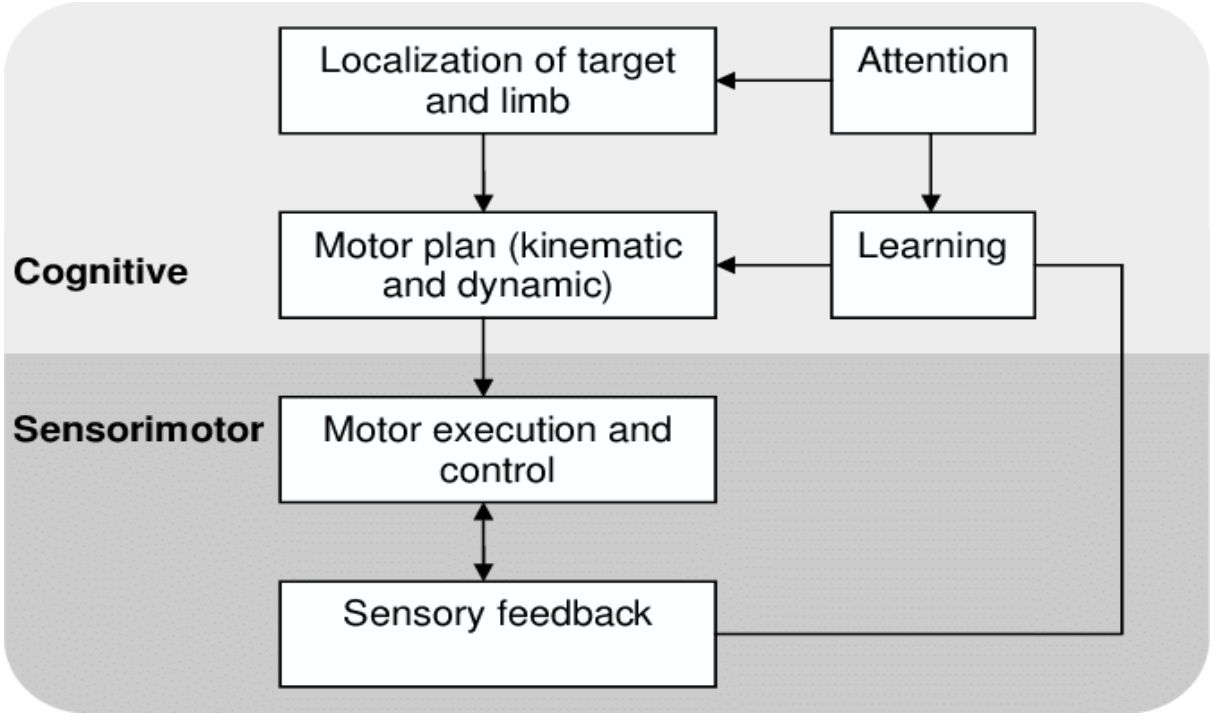
Motor Planning vs Learning

- Motor Planning
  - Taking sensory cues in the environment and appropriate processing of sensory input to select an optimal plan
- Motor Learning
  - Experience-dependent acquisition of a motor skill or adaptation of a motor skill when task conditions change




Motor Cortex Circuits
Layer V
Neurons
Corticospinal
Tract
Spinal Cord
Circuits
Spinal Neurons
Golgi Tendon
Organs
Muscle
Spindles
Muscle Fibres

SRC Can Motor Planning and Motor Learning



Due to “axonal damage from impact causes disruption of axonal transport, swelling and axonal disconnection” motor learning and motor planning can be affected. [6]

Cortical Hypoexcitability

Research Article

Cortical hypoexcitability persists beyond the symptomatic phase of a concussion

Kaley C. Powers, Michael E. Cinelli & Jayne M. Kalmar

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Primary objective: The purpose of this research was to assess cortical excitability, voluntary activation of muscle and force sensation beyond the initial highly symptomatic period post-concussion (1–4 weeks post-injury). It was hypothesized that reduced excitability of the motor cortex may impair muscle activation and alter perceptions of force and effort.

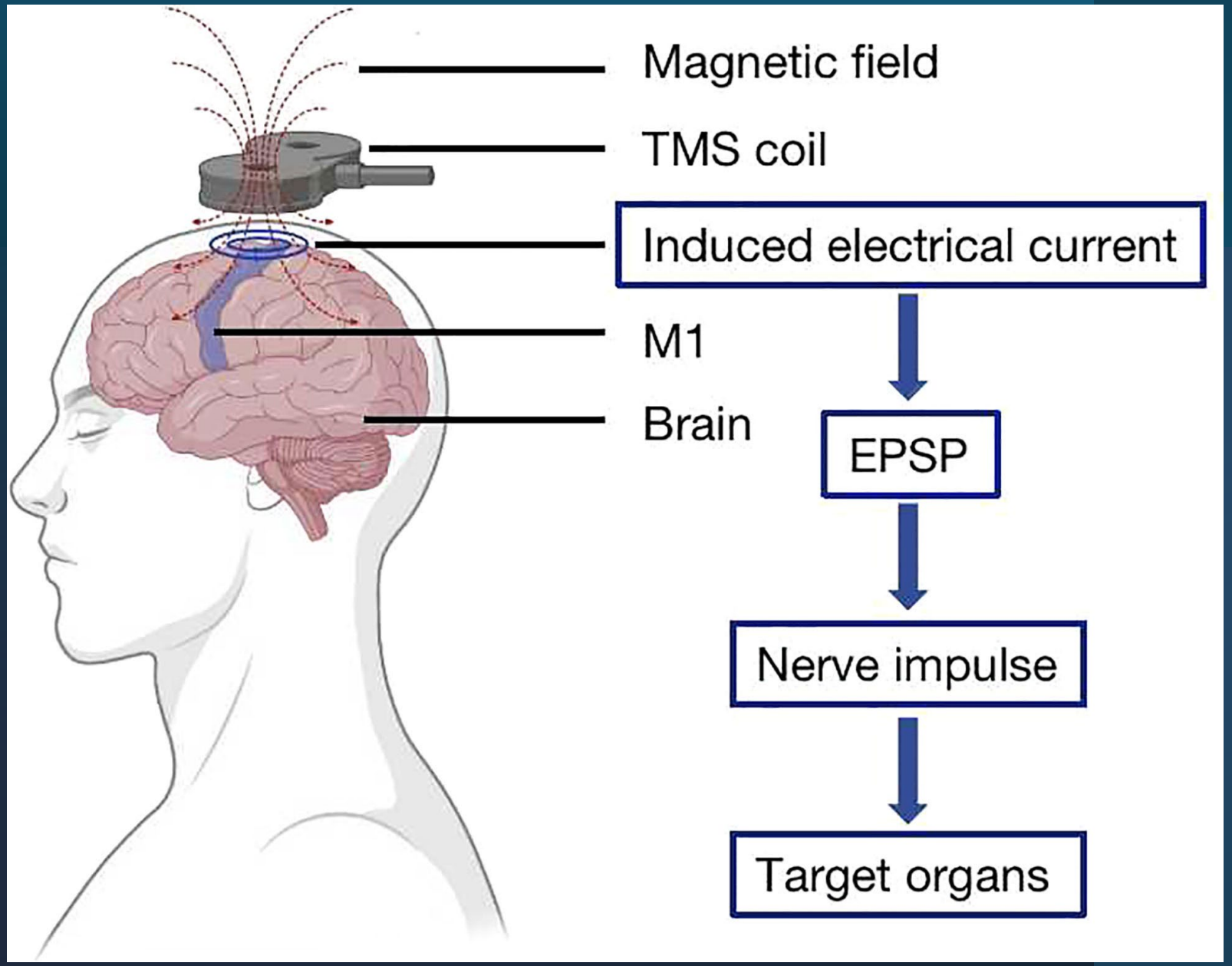
Research design: Eight concussed varsity football players were age- and position-matched with eight healthy teammates to control for training and body size. Healthy controls had not suffered a concussion in the previous 12 months.

Methods and procedures: Paired-pulse transcranial magnetic stimulation was used to assess cortical excitability, voluntary activation was calculated using cortical twitch interpolation technique and sense of force was determined using constant-force sensation contractions.

Main outcomes and results: The concussed group had lower intra-cortical facilitation ($p = 0.036$), lower maximal voluntary muscle activation ($p = 0.038$) and greater perceptions of force ($p < 0.05$), likely due to compensatory increases in upstream drive, than their healthy matched teammates.

Conclusions: Taken together, these findings suggest a state of hypoexcitability that persists beyond the immediate acute phase of a concussion and may result in neuromuscular impairments that would call to question the athlete's readiness to return to sport.

[7]


Magnetic field
TMS coil
Induced electrical current
M1
Brain
EPSP
Nerve impulse
Target organs

[8]

Decreased Cortical Excitability = Altered Motor Control

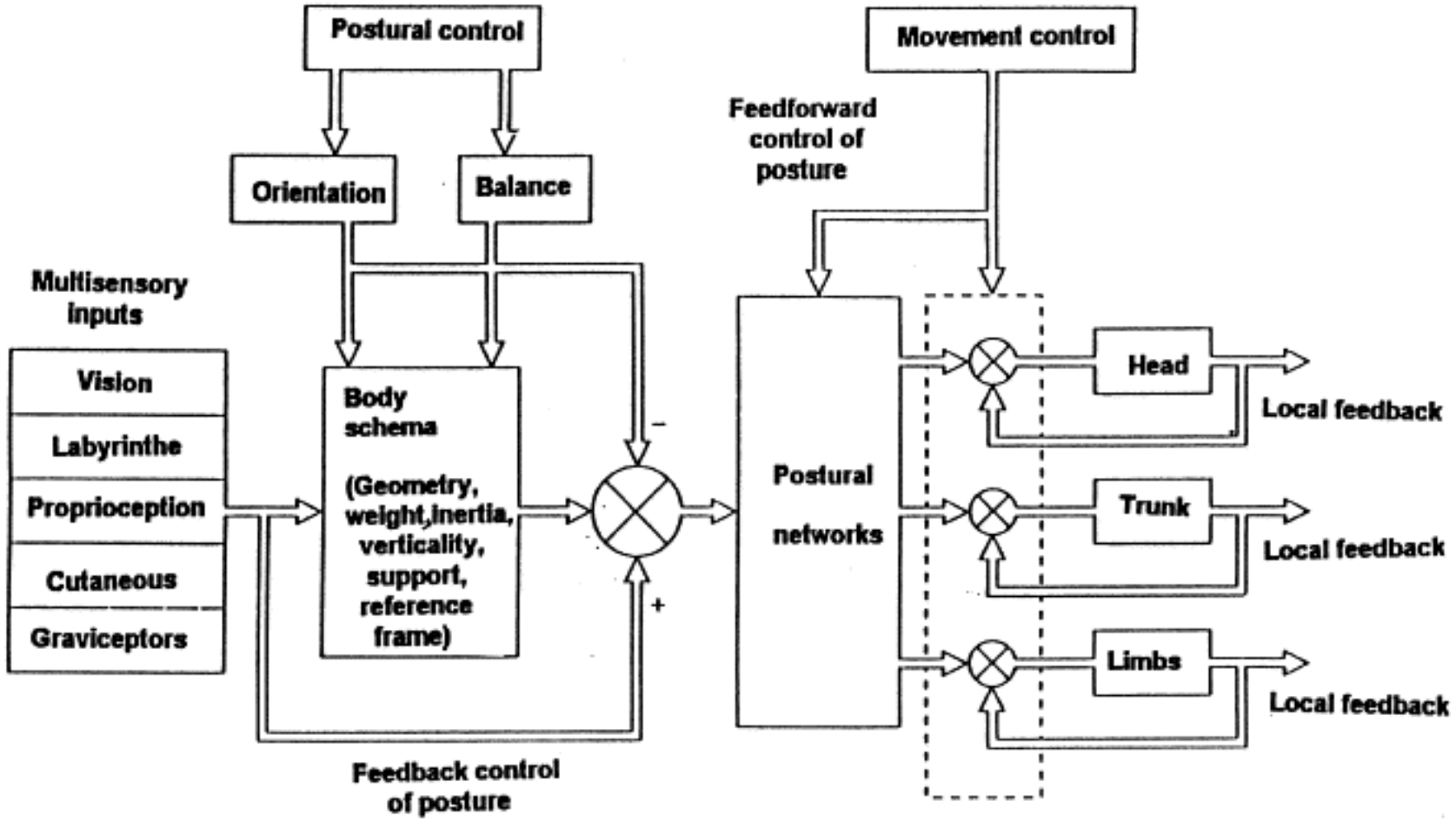
- SRC can impact cortical excitability
- Motor planning and learning ability decreased
- If the sensory system is unable to accurately perceive or process appropriately, motor function will be affected in the following ways:
    1. Muscle Force Perception
    2. Muscle Effort Perception
    3. Muscle Fatiguability

Clinical Assessments to Consider

- Decreased reaction times (visual/verbal)
- Poor Postural Control
- Decrease muscle activation and force production
- Modified Movement Patterns
- Impaired Motor Tasks performance with or without simultaneous cognitive task

Decreased Reaction Times

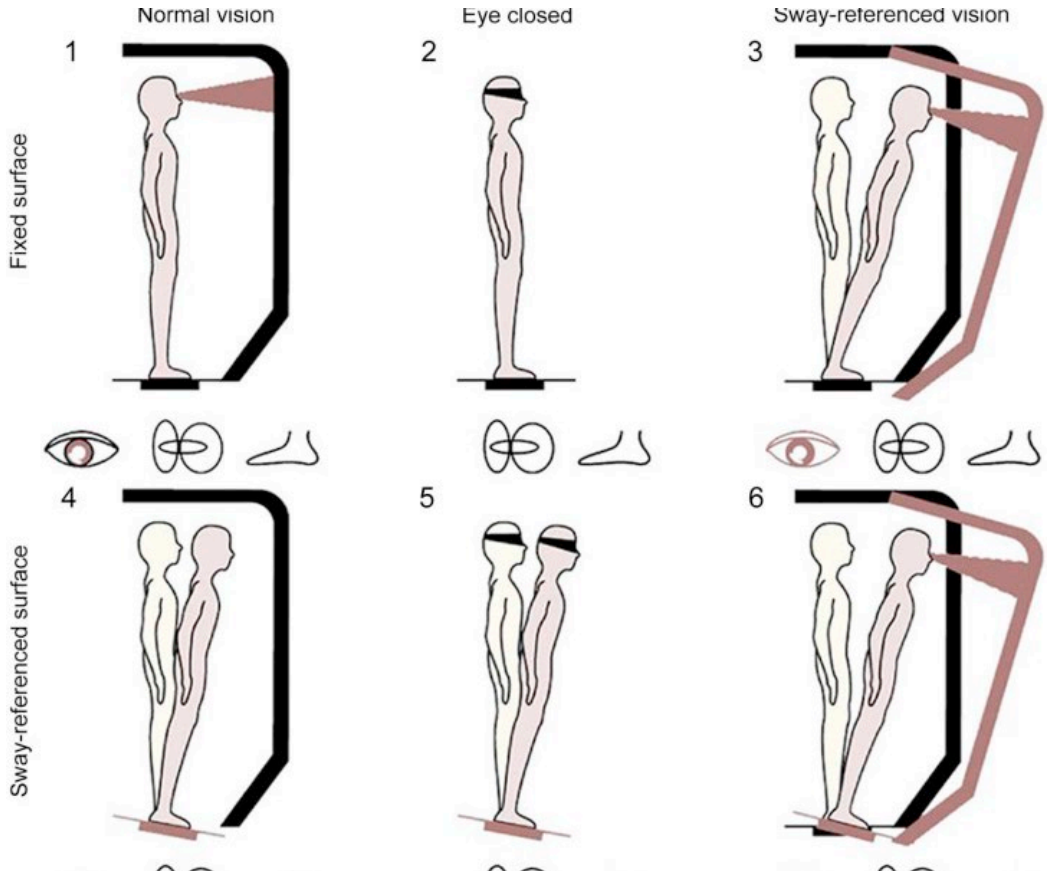
- Conclusion of This Study
  - “Neurocognitive reaction time appears to be an indicator of elevated risk for lower extremity sprains and strains among college football players, which may be modifiable through performance of exercises designed to accelerate neurocognitive processing of visual input.”



Postural Control Deficits

Sensory Organization Test

Used to objectively quantify and differentiate among sensory, motor, and central adaptive impairments to postural stability



Motor Control Test

Measures amplitude, latency, and symmetry of reflexive movements of postural control

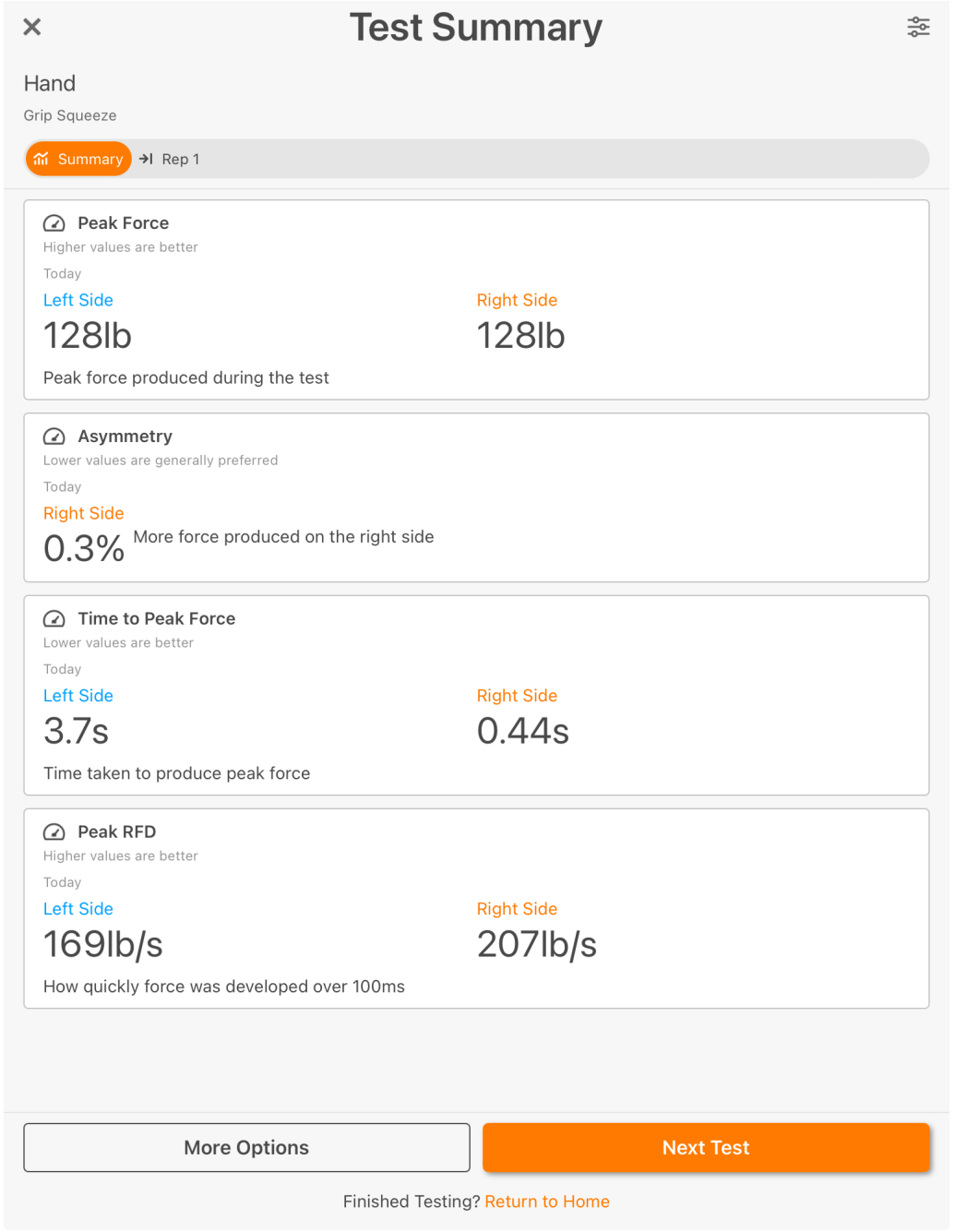
Identifies impairments in the first 160 mSec of after movement

Test looks at changes in center of mass (CoM) in response to a rapid change in environmental inputs

Decrease muscle activation and force production

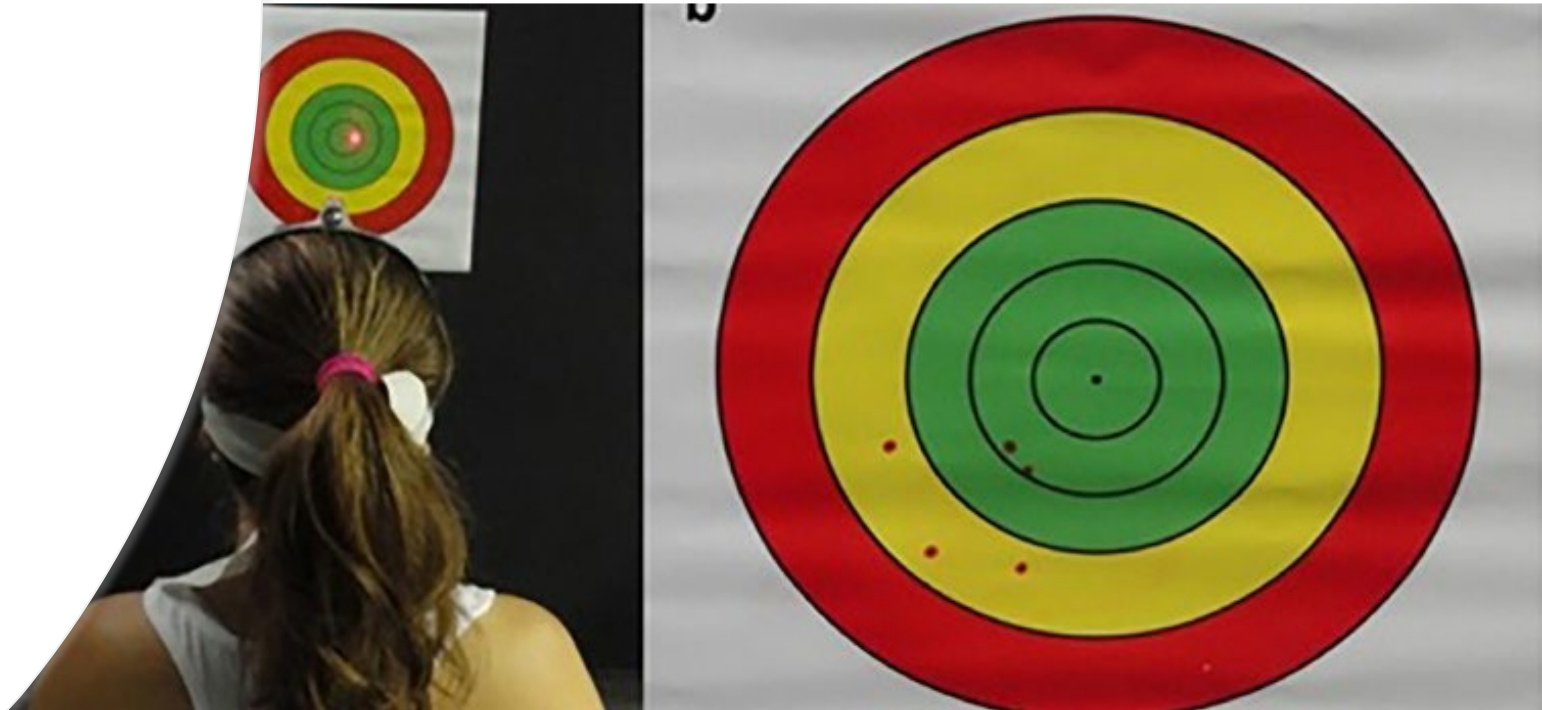
- Data To Consider
  - Max Force
  - Time to Peak
  - Force Variability
  - Symmetry of Force Production

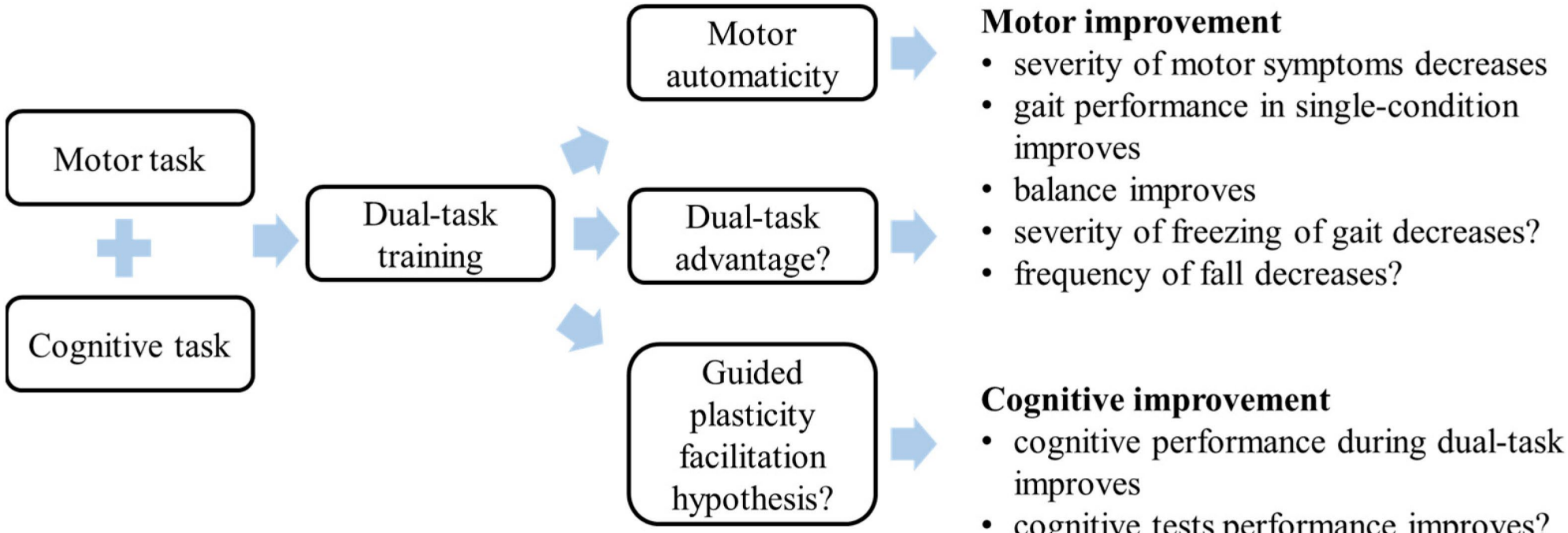
Video of VALD Dynamometer



Modified Movement

- Alteration of inter-joint coordination and changes in perceived Center of Mass could be the reasons for altered movement patterns
- Tests to consider
  - Joint Position Error Testing
  - Two-Legged Jump-Landing Task





Dual Task Control Deficits

- Dual-Tasking/Attention Neuromuscular deficits
  - Brain's ability to integrate cognitive and motor information
  - More reflective of sports participation than single task balance or cognitive assessments

Assessing Dual Task Deficits

- Dual Cognitive Motor Assessments
  - Standing on one foot while performing word generation
  - Walking over obstacles while subtracting by 7’s
  - Transferring coins between pockets and while subtracting by 3’s
  - Finger-to-nose as fast as possible while counting to 100

Other Potential Useful Testing to Consider

- Buffalo Treadmill Test (Exercise Tolerance Testing)
- Autonomic Testing
  - Pupillometry
  - Postural Blood Pressure Testing

Buffalo Concussion Treadmill Test

- A validated test to assess the aerobic capacity that is safe for an athlete to perform.
- Identifies the heart rate threshold (HRt) of exercise tolerance in concussed patients.

Autonomic Testing

- Pupillometry
  - The measure of the pupils in response to light exposure
  - “The PLR variables of latency, maximum pupil diameter (MaxPD), minimum pupil diameter (MinPD), maximum constriction velocity (MCV), and the 75% recovery time (75% PRT) were associated with significant differences between subjects who had suffered a concussion and those that had not.”

	Right	Left
NPi	2.2	1.1
Size (mm)	3.97	4.20
Min (mm)	3.54	4.04
CH	11%	4%
CV (mm/s)	0.61	0.22
MCV (mm/s)	0.97	0.53
Lat (sec)	0.33	0.13
DV (mm/s)	0.15	0.05

b

Autonomic Testing

- Postural Blood Pressure Testing
    1. Have the patient lie down for 5 minutes.
    2. Measure blood pressure and pulse rate.
    3. Have the patient sit.
    4. Repeat blood pressure and pulse rate measurements after standing 1 and 3 minutes.
    5. Have the patient stand.
    6. Repeat blood pressure and pulse rate measurements after standing 1 and 3 minutes.
- A drop in BP of ≥20 mm Hg, or in diastolic BP of ≥10 mm Hg, or experiencing lightheadedness or dizziness is considered abnormal.

Why does this all matter?

Movements in sports is just a series of motor tasks performed in a rapidly changing environment.

Often, concussion assessments and treatments are very narrow sighted and fail to address the multifactorial nature of these injuries

Being able to understand and implement one of these assessments might help ensure an athlete can make a more complete recovery

Guided Plasticity Facilitation Hypothesis

- The guided plasticity facilitation hypothesis may contribute to the improvement in cognition by motor-cognitive dual-task training.
- In this hypothesis, motor training facilitates the neuroplasticity and cognitive training guides the neuroplasticity.
- An experiment in mice found that exercise can stimulate hippocampal neurogenesis. Mouse undergoing exercise and cognitive stimuli (environmental enrichment) recorded a greater increase in new neurons in the dentate gyrus compared to that in mice with single exercise or cognitive stimuli

Future Considerations

- A change in basic concussion assessments should include more detailed motor control testing
- These assessments discussed today in addition, should be considered to ensure that athletes are not returning to play
- It is important to remember that while testing these in isolation can help us identify problems, a rehabilitation program should always aim to integrate

Discussion

The current concussion management typically recommended by most providers is rest until symptoms resolve

This could affect all the things we discussed today

The brain is sensory dependent system and if we deprive it of that input for rest, then we put patients at a greater disadvantage in its recovery.

Conclusion

Motor control systems can be impaired by SRC

Improvements in clinical assessment of motor control is needed to better manage SRC even after return to play protocol has been initiated.

Understanding that injuries to the brain also effect musculoskeletal systems will improve patient outcomes.

Questions?

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